

CHAPTER V

FINDINGS: TIME FRAME COMPARISONS

To improve our understanding of the effects of the technology transfer legislation, this study compared a 1980s group of pre-legislation cases with a 1990s group of post-legislation cases. A number of findings emerged from that analysis. Table G, “Similarities and Differences Between the Two Time Frames” lists the findings according to the interview topics (at the end of the chapter).

In this chapter, the findings are grouped and discussed according to their impact on technology transfer outcomes and process. Section A discusses those findings indicating a positive impact, while sections B and C present findings with no impact or negative impact, respectively.

A. GOVERNMENT TECHNOLOGY TRANSFER IMPROVED

The technology transfer legislation has had a positive effect on technology transfer outcomes and process, as summarized below:

1. **Researchers’ Roles** - Researchers produced more prototypes and samples.
2. **University Involvement** - The university role became more institutionalized.
3. **Intellectual Property** - Laboratory patenting increased.
4. **Technology Transfer Mechanisms** - Researchers displayed increasingly strong opinions about licensing royalties.
5. **User Groups** - (a) Small-firm involvement increased; (b) The transfer process shifted from technology push to market pull; and (c) Users narrowed from broad groups to targeted markets.
6. **User Benefits/Economic Impacts/Outcomes** - (a) Number of products increased; (b) Sales revenues increased, including international activity; (c) Number of spinoff start-up companies and jobs generated increased; (d) Company and product failures decreased; and (e) Dual uses, government gains, and spinbacks increased.
7. **Elapsed Time** - The time to market decreased.

A.1 Researchers' Roles - Researchers Produced More Prototypes, Laboratory Samples

In the 1990s cases, the researchers produced more laboratory prototypes and laboratory material samples than in the 1980s cases. In the 1980s cases, laboratory material samples were developed in the (1) thermoplastic materials and (2) the chemically-imbedded herbicide/pesticide.¹

The majority of the researchers in the 1990s cases developed prototypes and samples as part of their role in the technology transfer process. These cases involved the (1) laser-illuminated biological samples, (2) paper-quality tester, (3) microwave oven, (4) gravity meter, and (5) blood-flow diagnostic system. The scientists developed laboratory samples for the two materials-oriented technologies in the later group, (6) Oatrim and (7) the light sticks.

A.2 University Involvement - University Role Became More Institutionalized

In both the 1980s and 1990s cases, universities were involved in government technology transfer. In the 1980s, interactions took place at the individual scientist level, whereas in the 1990s cases, formal inter-institutional ventures characterized the joint government/ university work.

The university work in the 1980s cases involved professors and graduate students on an individual basis at the level of the bench scientist, as follows: (1) penetrometer - prototype development by a university professor; (2) thermoplastic material - on-site graduate student co-inventor; (3) tracer technology - graduate assistants for various demonstrations; and (4) alginate-based herbicide/pesticide - university professor co-inventor.

The university work in the 1990s cases involved teams of university researchers, and resulted from inter-institutional structures or ventures, as follows: (1) voice coder - university technology development work and spinoff company; (2) paper quality tester - technology testing and screening by universities; (3) gravity meter - joint government/ university laboratory development; and (4) artificial heart pump - university CRADA partner.

A.3 Intellectual Property - Laboratory Patenting Increased

Laboratories and their company partners both pursued patents more aggressively in the 1990s cases than in the 1980s cases.² For the five patentable technologies in the 1980s cases:

¹The only prototype development work in the 1980s cases was not performed by the laboratories, but was contracted out -- to a university engineering department (in the penetrometer case) and to instrument makers (in the tracer technology case).

²Other aspects of intellectual property remained the same. For example, the laboratory researchers from both the 1980s and 1990s cases did not elaborate or provide details on invention disclosures. None of the cases in this series involved filing a provisional application, an option under the new international patent regime. Also, the issue of software copyrighting did not come up because there were no cases centered around software development;

(1&2) The relevant agencies patented the two herbicide/ pesticides several times in each application area.³ (3) NASA patented the thermoplastic material twice through joint laboratory-university filings. Additional findings are less positive: DOE patented the tracer technology, with its practically limitless applications, only once.⁴ Also, the Navy researcher attempted to patent both versions of the penetrometer, but was denied application filings by the Navy.⁵

In the 1990s cases: (1) Iowa State, DOE's contracting laboratory operator, patented the laser-based method for lighting up biological samples. The U.S. Department of Agriculture patented the (2) paper-quality tester and (3) fat substitute. (3) Both the Navy and its corporate licensees patented the light sticks many times.⁶ (5) Both DOE and Baxter Healthcare patented the blood-flow technique. (6) Oak Ridge filed several patents jointly with its spinoff company and other research partners for the microwave oven.⁷ (7) For the voice coder, the Air Force was not the developer of the technology and couldn't patent it, but the spinoff company patented it several times. In the remaining case, the company currently producing the gravity meter considers the technology proprietary, although neither NIST nor the company patented it.⁸

A.4 Mechanisms - Researchers Had Increasingly Strong Opinions About Royalties

In the context of most laboratory budgets, royalty income is not that significant (although it may become more important as budgets decline). For example, China Lake received a little over \$86,000 in royalties for its licenses on the light-stick technology. However, at the level of the individual researcher, licensing royalties provide important incentives to transfer

an FLC award in the 1985-1986 time frame was for a geographical information system, but it was not developed into a case for this dissertation. The only aberration in terms of intellectual property issues related to the litigation in the light stick case, which is illustrative of the fact that patent court cases are becoming more common.

³However, there were still some intellectual property lessons to be learned in one of these 1980s cases where the researcher shared his knowledge about his technology during a corporate visit to his office, only to find the company avoided his patent when commercializing.

⁴The inventor of the tracer technology commented that laboratory researchers tended not to patent until recent years.

⁵The inventor of the penetrometer said that in the 1980s when he attempted to transfer the technology, a patent counted only about as much as a publication toward professional advancement. Further, Navy scientists received \$50 to 100 per patent, which was not much incentive.

⁶However, the inventor of the light-stick technology said he was denied patent filing for the fishing lure application because the Navy did not want to spend the money it would have cost to file.

⁷Furthermore, the chief scientist in the microwave oven case, who had a portfolio of twenty patents and fifteen pending, was sought out by proteges for his patent-related advice.

⁸The inventor of the unpatented gravity meter said that, until about five years ago, NIST urged its researchers to publish rather than patent.

technologies. Apparently, these payments are becoming more meaningful because the researchers' opinions about royalties were strong in both the 1980s and 1990s cases, becoming stronger in the 1990s.⁹

In the 1980s cases: (1) The chief scientist in the thermoplastic material case provided detailed information about the royalty sharing arrangements in the case of multiple inventors from different institutions, and opined about what the laboratory should do with its portion of the royalties. He also recommended that mechanisms to handle royalty-sharing disputes be created. (2) The researcher in the alginate-based case commented on the amount of royalties an ARS scientist receives when a USDA patent is licensed.

In the 1990s cases: (1) The inventor of the laser-based method for lighting up samples stated that only one in a hundred products on the market benefits the actual laboratory inventor financially. (2) The chief scientist in the microwave oven case was stated that royalty payments to the laboratory scientists should be a secondary consideration in terms of the overall legal agreements between laboratories and companies. In the same case, the head of the partnering company stated the importance of sharing a percentage of the royalties with the partnering laboratory inventors to give them an investment in his company's success. (3) A USDA scientist in the alginate case referenced the inventor in the Oatrim case, widely known for making the most of the new technology transfer incentives. (4) The lead researcher in the light-stick case provided details about the laboratory's royalty-sharing arrangements and his views about the contribution of patents toward promotions. He said that if he'd had the foresight to file a patent on a frisbee made with the chemiluminescent materials, he'd be a millionaire by now! A "Success Story" sheet from his laboratory stated that the royalties provided an incentive to other inventors in the same laboratory. (5) The chief scientist in the gravity meter case commented on the royalties he missed by not patenting the gravity meter. He also noted that some agency incentives for transferring technology were better than others. As an example, he said that other FLC awardees received bonuses with their technology transfer award while he did not.

A.5 User Groups

The user groups and laboratory partners became more small firm-oriented and targeted.

⁹It is debatable whether the researchers' strong opinions regarding royalties are an indication of improvement or of greater awareness. In either case, an assumption underlying the legislation is that such incentives would have an effect, so this change is viewed as an overall positive sign and is, therefore, included in this first section (Section A) about positive changes.

A.5(a) Small-Firm Involvement Increased

In the 1990s cases, more small firms were involved in technology transfer activities than in the 1980s cases. Overall, small firms comprised ten of the 31 technology partnering companies (three from the 1980s cases and eight from the 1990s cases), an indication that small firms have become more involved in technology transfer efforts.

In the 1980s cases, the three small firms included: (1) High Technology Services in the thermoplastic material case, (2) AIM Inc. in the tracer technology case, and (3) Thermo Trilogy Corporation in the alginate-based herbicide/pesticide case. Large corporations comprised the remainder of the partners in the 1980s cases, including Hoescht-Celanese Corporation, M&T Chemical, Consolidated Edison, Grace-Sierra, Mycogen Corporation, Reemay Inc., and Geoflow Inc. The interviewees did not identify the other 1980s partners as large or small.

In the 1990s cases, the eight small firms included: (1) Digital Voice Systems, Inc. in the voice coder case, (2) Isthmus Engineering and Manufacturing Co-op in the paper-quality tester case, (3 & 4) Microwave Laboratories Inc. and Lambda Technologies in the microwave oven case, (5, 6 & 7) Axis Instruments, Micro-g Solutions, Winters Electro-Optics in the gravity meter case, and (8) OmniGlow Corporation in the light stick case. The 1990s cases involved several large corporations, including ConAgra, A.E. Staley Manufacturing, Quaker Oats, Rhone-Poulenc Inc., and Baxter Healthcare. The interviewees did not identify the remaining 1990s partners as large or small.

A.5(b) Process Shifted from Technology Push to Market Pull

“Market pull” characterized the transfers in the 1990s cases, while “technology push” characterized the transfers in the 1980s cases. Users or partners initiated contacts with the laboratory researchers in the 1990s cases, whereas the laboratory scientists initiated most of the contacts in the 1980s cases.

The 1980s “technology push” cases included the: (1) penetrometer, (2) thermoplastic material, (3) substance tracer, (4) chemically-based herbicide/pesticide, and (5) radiation therapy. (6) In the case of the alginate-based herbicide/pesticide, both market pull and technology push were at work. The original Grace-Sierra work stemmed from existing relationships between the company and USDA. Later, Biosys, Inc. and EcoScience contacted the USDA scientist.

Five of the 1990s cases were market pull, while three were a combination of technology push and market pull. In the 1990s (1) paper-quality tester and (2) gravity-meter cases, Isthmus Engineering and Axis Instruments both responded to competitive solicitations from their developing laboratories. (3) Similarly, the Oatrim manufacturers responded to the developing laboratory’s request for expressions of interest at a technology transfer conference for industry. (4) The artificial heart testers and manufacturer contacted the DOE laboratory in search of a

workable technology. (5) Originally, laboratory researchers sought out the microwave oven manufacturers, but the “replacement” manufacturer sprang up specifically to manufacture the laboratory’s technology. (6) The voice coder, (7) light sticks, and (8) laser-based luminescent technologies all involved both technology push and market pull. For example, the university laboratory that developed the voice coder was seeking funding from a federal agency, but once the agency understood the technology’s potential, it not only funded it but also pushed it to standard-setting organizations.

A.5(c) Users Narrowed from Broad Groups to Targeted Markets

The 1990s cases had more targeted and specific technology user groups than the 1980s cases. The 1980s cases involved earlier-stage technologies, so the user groups were broad-based and not as market-oriented.¹⁰ For example, both (1) the thermoplastic material and (2) tracer technology had a broad range of existing and/or potential users. The same was true for the (3&4) two herbicide/ pesticide technologies. Although based in very different materials, each appealed to agricultural, public works, and home owning groups.¹¹ (5) Addressing requirements for oceanography and waterway projects, the penetrometer was used by government organizations, whether state, local or federal. (6) The radiation therapy system, which expanded to include radiation protection, was intended for medical and industrial arenas.

The 1990s cases had more targeted user groups and markets. (1) The voice coder addressed telecommunications industry needs. (2) The paper testing technology solved storage problems for paper product manufacturers. (3) The gravity meter provided measurements for geological, climate, and environmental programs. (4) The fat substitute was an ingredient used by producers of processed foods and meals. (5) The blood flow diagnostics assisted the heart transplant portion of the medical community. (6) The microwave furnace was employed in laboratories of all types (university research, commercial testing, etc.) and later targeted to manufacturing environments. (7) If commercialized, the laser-based method for illuminating biological samples would appeal not only to research laboratories, but to chemical and pharmaceutical laboratories (eg., clinical, pharmaceutical). (8) The light-stick technology was the most broad-based of all the technologies, being applicable to everything from defense reconnaissance to toys, and from industrial plants to medical clinics, and likewise to both the recreational and commercial fishing industries. Omniglow even provided its chemiluminescent materials to high schools for science experiments.

¹⁰The radiation therapy quality assurance program was standards-oriented rather than market-oriented.

¹¹With one exception: the alginate-based herbicide/ pesticide could be used by landscape firms to control weed and pests slowly; the chemically-imbedded herbicide/ pesticide was so long-term oriented that landscape outfits saw it as competition in the sense that a major portion of their maintenance services would not be necessary.

A.6 User Benefits/Economic Impacts/Outcomes

Compared to the 1980s cases, the 1990s cases exhibited greater economic impact in terms of increased number of products, sales revenues, spinoff start-up companies, and jobs generated. Combined with a decline in company and product failures, and an increase in dual uses and government gains, these findings indicate significant improvements in technology transfer results.

A.6(a) Number of Products Increased

The 1980s cases produced sixteen successful products or product lines, whereas the 1990s cases produced 114 successful products. In the 1980s cases, successful commercial products included:

- (1) **Thermoplastic material** - M&T-4605; Techimer 4001
- (2) **Tracer technology** - “COPS” substance tracer/sniffer
- (3) **Alginate-based herbicide/pesticide** - GlioGard™ Biological/Microbial Fungicide, BioSafe^R 20 and BioSafe^R 100 Insect Control, SoilGard™ 12G Microbial Fungicide, Aqua-Fyte™ Bio-herbicide, Vector^R MC for mole crickets, Lesco™ Vector^R MC Insect Control, and BioVector^R 355 for citrus weevils
- (4) **Chemically-imbedded herbicide/pesticide** - Rootguard^R Subsurface Irrigation Systems, including an entire line of irrigation products, Biobarrier^R Root Control System, Biobarrier^R II Preemergence Weed Control System, Root Shield™, and Grow Guard

In the 1990s group of cases, the following products made it to the commercial marketplace:

- (1) **Voice coder** - IMBE™ Speech Compression Systems, IMBE™ VC-20 Voice Codec Module, IMBE™ VC-100 Voice Codec Module, AMBE^R Speech Compression System, and AMBE-1000™ Coder
- (2) **Paper quality tester** - Vacuum Compression Apparatus, Thin Film Analyzer
- (3) **Microwave oven** - Variable-Frequency Microwave Furnace, Applicator, Processing System, Traveling Microwave Tube Amplifier, Vari-Wave multi-functional microwave oven, Vari-Data hardware/software interface
- (4) **Gravity meter** - FG5 “Gravimeter,” Gravity Meter, Iodine Laser
- (5) **Oatrim fat substitute** - TrimChoice, Beta-Trim

- (6) **Light sticks** - S.E.E.TM Emergency Evacuation Systems, Flex-Stick^R fishing lures, Speculite^R, Cyalume^R, Snaplight^R, Lite-Up^R and Glow Stick^R light sticks, PML^R stick-on buttons, Lightwrap^R glowing strips, “Flourescers,” Lite-Rope^R necklaces, and Magic in the NightTM earrings, bracelets and eye glasses. Most of these products are offered in various sizes and colors, for a total of over 100 products
- (7) **Heart-flow diagnostics** - Left Ventricular Assist Device (LVAD) artificial heart pump.

Not only did the number of products increase, but also two companies involved in post-legislation cases reported on the specifics of their commercial success. Lambda Technologies received orders for two to three microwave units a month in 1996 compared to none when the company was first spun off. Omniglow produced over 250 million lights sticks since the early 1990s.

Several products were taken off the market and replaced by other products, reflecting changing corporate priorities. In the 1980s group, these products included GlioGardTM Biological/Microbial Fungicide, BioSafe^R 20 and BioSafe^R 100 Insect Control in the alginate-based herbicide/pesticide case. In the 1990s group, they included the FG5 Gravimeter from the gravity-meter case.

A.6(b) Sales Revenues Increased, Including International

Most of the privately-held companies were reluctant to reveal revenues associated with their products. In the 1980s cases, very little information was made available on the sales revenues of the companies.¹²

In the 1990s cases, four companies provided sales revenues amounting to a total of \$7.7 million in revenues. (1) The cooperative producing the paper quality tester realized almost \$500,000 in sales from the Forest Products Laboratory technology. (2) The first company producing the gravity meters sold \$3 million in gravity meters before going out of business; its spinoff did almost \$2.5 in sales of gravity meters after that. Another spinoff manufacturing a major gravity meter component had realized \$1.2 in sales or almost \$500,000 in gross revenues.

¹²(1) Because the tracer technology proved to be not viable as a stand-alone business venture, at least three small firms sold the tracer service and/or instruments as “sideline” businesses. However, the laboratory scientist who developed the technology said the firms had not realized more than a few thousand dollars worth of business in this area. The laboratory, itself, offered tracer technology services for a fee. (2) Thermo Trilogy from the 1980s alginate-based herbicide/pesticide case noted that the company would not be able to provide sales figures until it goes public.

On a related note, both the 1980s and 1990s cases, with one exception (the 1980s penetrometer case), reported international commercial activity of some sort; however, the companies involved in the 1990s cases indicated substantially more international sales than the companies in the 1980s cases.¹³ Only the (1) chemically-imbedded herbicide/pesticide in the 1980s group of technologies had significant international commercial sales. For example, Agrifim International's marketing materials listed major systems installed in other countries. From the 1990s time period, several companies enjoyed significant international commercial sales. These included companies in the (1) gravity meter, (2) fat substitute, and (3) light stick cases.

A.6(c) Number of Spinoff Start-up Companies, Jobs¹⁴ Increased

In contrast to the 1980s cases (none of which led to the creation of spin-off companies), the 1990s cases produced six new companies to commercialize the technology developed in the case. For example, (1) Digital Voice Systems, Inc. was established to commercialize the voice coder, and (2) Omniglow, Inc. was created to advanced the light stick technology. (3) Lambda Technologies, a spin-off of the bankrupt Microwave Laboratories Inc, commercialized the microwave oven.¹⁵ (4) Axis Instruments, founded to commercialize the gravity meter, later spawned Micro-g Solutions and Winters Electro-Optics when it closed its doors. The lead scientists for both the microwave oven and the gravity meter¹⁶ described the resulting spin-off companies as “a phoenix rising out of the ashes.”

Although the companies involved in the 1980s cases did not provide any employment data, none was dedicated exclusively to the laboratory technology as occurred in the 1990s cases.

Six companies in the 1990s group of cases provided the number of jobs generated by the laboratory-developed technology; a net total of 348 new jobs were created. (1) The company commercializing the voice coder employed “about ten” people since its founding in the 1980s.¹⁷

¹³Consistent with the companies' reluctance to share sales revenues, they did not provide precise international sales figures.

¹⁴State government technology programs are often administered by state economic development agencies, the majority of which use job creation as their key measure of success according to a 1996 survey by the National Association of State Development Agencies. A problem, however, is that they measure jobs on an annual and regional basis rather than a cumulative and per-project basis, making this difficult to apply to longer-term technology transfer and commercialization.

¹⁵DOE publications are not accurate in saying that Microwave Laboratories formed the new company.

¹⁶In a presentation at an FLC meeting.

¹⁷The group of university researchers forming Digital Voice Systems, Inc. received funding from other sources besides the Air Force so it is not clear how much of the credit the Air Force can claim for this success.

(2) In the microwave oven case, Lambda Technologies grew from four to nineteen employees, and projected adding several new positions by the end of 1996. (3) The first company producing gravity meters employed about twenty people before it went out of business, but two new spinoff companies, Micro-g and Winters Electro-Optics, employ eight and two people, respectively. (4) In the light stick case, Omniglow increased from three to three hundred employees since its founding in the late 1980s. (5) Although the 1990s Oatrim fat substitute case involved very large companies, specific divisions or sales groups were dedicated to the laboratory technology. The Mountain Lake “Trimchoice” manufacturing facility employed nine people, and the Quaker partnership included a sales force of about two dozen persons dedicated to its Beta-trim product.

A.6(d) Company, Product Failures Decreased

The companies in the 1990s cases experienced fewer technology transfer and commercialization failures than companies involved in the 1980s cases. Most of the failures in the series of cases came from the 1980s cases, with a couple of exceptions.

In the 1980s time frame, five of the commercializing companies were subject to corporate buy-outs, take-overs, or company failures which, in turn, affected the outcome of the technology. Also, in at least five of the 1980s cases, production costs were prohibitive. As a result, two products stopped short of the commercial marketplace, and of the commercialized products, five technology licenses were inactive although three commercial products resulted from them. (1) The penetrometer technology did not make it to the commercial marketplace, and was eventually supplanted by a more cost-effective and improved technology. (2) The thermoplastic material product, M&T-4605, also failed through two licensees¹⁸ because of changing company strategies and high production costs, although the small company that continues to hold an active license hopes the technology will succeed commercially. (3) There were also several failures in the alginate-based herbicide/ pesticide case. A problem experienced by all of the companies in this case was the high cost of raw materials. One of the original licensees, Mycogen, never commercialized any products, and another company tested its Aqua-Fyte™ Bio-herbicide in EPA field experiments, but did not commercialize.¹⁹ Two additional companies experienced changes in business ownership and resulting changes in product lines that precluded the development of certain of the alginate-based products. (4) In the chemically-imbedded herbicide/pesticide case, the companies producing Root Shield™ and Grow Guard did not pursue their markets aggressively and the licenses became inactive.

In the 1990s group, there was one license failure in the case of the laser-based biological samples. Apparently, the company did not want to invest in the laboratory prototype, in spite of it being customized to the company’s equipment, reflecting a syndrome in American industry

¹⁸The two original licenses for the thermoplastic material are inactive.

¹⁹The product was abandoned when the company failed financially.

known as “NIH” or not-invented-here.²⁰ The only failed commercial product in the 1990s group resulted from overall company failure, namely Microwave Laboratories and its line of variable-frequency microwave oven products: the Variable-Frequency Microwave Furnace, Applicator, Processing System, and Traveling Microwave Tube Amplifier. However, the technology survived; the microwave oven was being produced by another company that spun out of the original failed company.

A.6(e) Dual Uses, Government Gains, Spinbacks Increased

Three cases in the 1980s and 1990s resulted in federal government gains and/or dual (military/civilian) uses. Of the 1980s cases: (1) The penetrometer was developed for state economic development purposes, but the Navy became the chief beneficiary, using six holotype versions of the invention. (2) In the case of the tracer technology, the developing laboratory (Brookhaven National Laboratory) received unexpected revenue by providing tracer services. (3) The chemically-imbedded herbicide/ pesticide was developed for use at radioactive military storage sites.

Five 1990s cases provided government benefits. (1) The Forest Service developed the paper quality tester for the paper industry, but the Bureau of Engraving and Printing was able to use the technology in its currency printing activities. (2 & 3) Both the voice coder and the microwave oven element were developed for military communication purposes. (4) NIST developed the gravity meter for environmental purposes, but the military services also purchased gravity meters for their use. (5) The Navy developed the light stick technology for military search and rescue purposes.

A.7 Elapsed Time - Time to Market Decreased

Development time, that is, the time from laboratory R&D to commercialization or pre-commercialization stages was seven to ten years less in the 1990s cases than in the 1980s cases. In the 1980s cases, the (1) penetrometer technology and (2) the quality assurance program did not involve commercialization. Of the remaining 1980s cases, many of the technologies were under development, as follows:

- (3) The thermoplastic material had spent fifteen years in the phases between conceptualization and pre-commercialization.
- (4) The tracer technology was under development for over twenty years. Because each existing application area reached a different stage of development at a

²⁰However, another factor may have been the fact that the University of Iowa’s license with Lachat Instruments was negotiated in the days when licenses were arbitrarily granted without requiring royalty payments; not even an up-front fee was requested as a good faith gesture in return for the cost of operating the license. This lack of value may have also contributed to the company’s lack of commercialization effort.

different time, the technology needed to be examined on an application-by-application basis. Because not enough data was available to do a mini-case study on each application, development was protracted.

- (5) The alginate-based herbicide/pesticide was under development for about twenty years.
- (6) The chemically-imbedded herbicide/ pesticide was under development for nearly twenty years, with different applications reaching the market at different times. However, the team leader emphasized that the ultimate value of this technology wouldn't become apparent for another fifteen to twenty years.

In summary, in the 1980s cases, fifteen to twenty years was the predominant development time frame.

In the 1990s cases, however, all eight technologies reached commercialization within eight to ten years:

- (1) The laser method had been under development for about ten years, although still not commercialized.
- (2&3) Both the voice coder and the paper quality tester were under development for about ten years before being commercialized.
- (4&5) The tunable microwave oven and the fat substitute were both market-ready in about eight years.
- (6) The gravity meter instrument reached the market in ten years, while the technology underlying the instrument was under development fifteen years before that.
- (7) The light-stick technology was first licensed in the late 1970s, less than ten years after its discovery, although it continued under development for fifteen years after that.
- (8) The blood-flow diagnostics application was under development for about eight years.

In summary, the cases showed that the legislation led to shorter development time frames. To get a technology from R&D to the marketplace took fifteen to twenty years in the 1980s cases and just eight to ten years in the 1990s cases. Table E summarizes the data on elapsed times.

B. CERTAIN ASPECTS DID NOT CHANGE

Certain aspects of the cases did not change, or remained consistent, from the 1980s (pre-legislation) time frame to the 1990s (post-legislation) time frame, as follows:

1. **Roles, Technologies, Laboratories, Funding** - Consistency characterized the “system” in both time frames: (a) many aspects of the researchers’ roles were consistent, (b) the technologies continued to represent diverse technology areas, (c) the laboratory groups remained similar, and (d) funding combinations remained similar.
2. **Technology Transfer Mechanisms** - Licenses and CRADAs predominated in both time periods.
3. **User Benefits/Economic Impacts/Outcomes** - Researchers and partners continued to describe success many ways: (a) they consistently used miscellaneous indicators; and (b) they consistently used intangible measures.
4. **International Activity** - The laboratories remained uninterested in obtaining foreign patent rights.
5. **Economic Development, Technical Assistance** - American-owned firms predominated in both time frames, but did not use available services.

B.1 Roles, Technologies, Laboratories, Funding

The government technology transfer system is represented by the roles, technologies, laboratories, and funding sources. Consistency characterized that system in both time frames.

B.1(a) Aspects of the Researchers’ Roles Were Consistent

Many aspects of the researchers’ roles did not change from the two time frames. The laboratory scientists in both the 1980s and 1990s cases were internationally-recognized experts. All scientists performed the traditional roles of research, publishing in scientific journals, and speaking at technical conferences to communicate their research findings with others in their fields. In both groups of cases, researchers cited a number of scientific and technical articles they wrote for reviewed journals. As noted in the alginate-based herbicide/pesticide case, USDA researchers “lived off publications” because that is how they were professionally graded.

TABLE E
ELAPSED TIMES

	Technology	Years under development
Pre-Legislation	Penetrometer (no commercialization)	-
	Thermoplastic material	15
	Tracer technology	20+
	Alginate-based herbicide/pesticide	20
	Chemically-imbedded herbicide/pesticide	< 20
	Radiation program (no commercialization)	-
Post-Legislation	Laser method	10
	Voice coder	10
	Paper quality tester	10
	Microwave oven	8
	Fat substitute	8
	Gravity meter	10*
	Light sticks	<10**
	Blood flow diagnostics	8

*Instrument, only, under development 10 years; technology an additional 15 years.

**Technology first licensed in 10 years; development continued 15 more years.

Most scientists interviewed weren't happy only performing basic or applied research; they also wanted to have their technologies put to practical use. From the laboratory researchers' perspectives, activities in this regard were meaningful whether a business venture failed (as with EcoScience Corporation in 1980s group, or Lachat Instruments' failure to invest in commercialization in the 1990s group). To the extent possible, the laboratory researchers "championed" their technologies by performing special activities to promote them. In the 1980s cases: (1) The inventor of the penetrometer used the prototype instrument to perform the survey work for the local government. (2) The developer of the tracer technology conducted numerous multi-party tests, large-scale demonstrations, and international experiments, and even produced a

video explaining the technology. (3) The creator of the alginate-based herbicide/pesticide explained how his technology worked to industry and university visitors in his laboratory. (4) Developers of the chemically-imbedded herbicide/pesticide tested their product at a nuclear waste site.

In the 1990s cases: (1) The inventors of the microwave oven sought out a company to manufacture the variable-frequency component and then concentrated on mentoring the eager young scientists at the partnering company. (2) The artificial heart-flow diagnostic researchers spent much time training CRADA partners on the flow diagnostic technique in their own laboratories. (3) Decades before the light sticks were commercialized, Navy researchers conducted numerous demonstrations in all types of settings, temperatures, and times of day. However, once licensing and commercialization ensued, these activities subsided over time.

In spite of the above explicit examples of enthusiasm, an undercurrent of caution on the part of laboratory researchers was also evident in both time frames, and the researchers seemed reluctant to pursue technology too aggressively. For example, the 1980s penetrometer case involved a patent filing rejection and a lack of encouragement by the laboratory regarding commercialization. However, the negative attitude on the part of the Navy laboratory may have been related to the classified nature of the technology.²¹ In the 1990s cases, in the gravity meter case, it was stated that some NIST employees were reluctant to talk with or work with companies. NIST was referred to as a “high-profile laboratory,” implying that it did not want to attract adverse publicity. Similarly, the researchers in both time frames expressed little interest in venturing outside their laboratories to start up businesses or become involved in other entrepreneurial activities.²²

In both the 1980s and 1990s cases, there were some but not many examples of references to market evaluations or technology assessments by the researchers. In the 1980s group: (1) In the chemically-based herbicide/pesticide case, the head of the research team provided market statistics in anticipation of future applications of the technology. (2) The only other case that with a similar level of market awareness was the thermoplastic material case, in which the laboratories were described as becoming more businesslike regarding technology transfer. The scientist in that case further commented that the NASA technology transfer offices seemed to be employing

²¹In contrast, the 1990s paper testing technology being used by the U.S. Bureau of Engraving and Printing which prints currency, also likely involved classified technology (the Forest Products Laboratory interviewee was reluctant to talk about that application). However, it did not seem to be a deterrent to transferring the technology to other applications in that case.

²²In the 1990s cases, the chief scientist in the gravity meter case expressed such an interest (possibly because one of his graduate students started one of the spin-off companies). He noted that scientists often feel a moral obligation to give back to society. However, he said regulations at his laboratory would not allow him to do so. Meanwhile, the PNNL leave-of-absence program has spawned ten new local businesses in less than two years by laboratory scientists, ranging from medical products to agricultural services; the Sandia National Laboratories entrepreneurial-leave policy involved five employees taking leave within a year to start businesses.

a “Madison Avenue-type of marketing.” However, this description applied to their technology marketing and deal-negotiating activities rather than to market analyses. There were no references to technology evaluations in the 1980s cases.

In the 1990s: (1) The paper-quality tester case provided the only example of a laboratory (the Forest Products Laboratory) making a conscious effort to develop a defined strategy for commercialization, including market assessment. The remainder of the cases in this group ranged in their approaches to market assessments. For example, in the gravity-meter case, NIST had been using a laboratory version of the gravity meter in its scientific work, and it wasn't until other agencies expressed interest in owning a gravity meter that the laboratory transferred the technology. In two of the 1990s cases, technology assessment work was performed: (2) In the paper-quality tester case, the laboratory issued cooperative research agreements to a number of universities and trade associations to evaluate the technology because of the need for a variety of manufacturing configurations. (3) In the microwave oven case, the Oak Ridge technology transfer office “spent money” to identify and assess “winner” technologies, which could mean they contracted out this activity.

B.1(b) Technologies Continued to Represent Diverse Areas

The technologies were diverse because the laboratories have a wide diversity of applicable technologies. Both the 1980s and 1990s cases included a representative range of technology and application areas, but with environmental technologies and biotechnology being especially evident -- which is not unexpected since they are two of the fastest growing fields of science.

Technology areas for the six technologies in the 1980s cases were: (1) oceanography, (2) materials, (3,4 & 5) three environmental technologies, and (6) medicine.

The technologies for the 1990s cases also involved a typical group of federal laboratory technology and application areas, including: (1) biotechnology, (2) telecommunications, (3) environmental technology, and (4) medicine. Two technologies were related to (5&6) industrial equipment, and two were related to (7&8) consumer goods. Each of these latter four technologies could be categorized in more than one technology area (materials, biotech, medical, etc.).

B.1(c) Laboratory Groups Remained Similar

There was little difference between the groups of laboratories in the 1980s and 1990s cases; both represented the range of federal/ national/ defense laboratories and field centers in this country. The 1980s cases involved USDA, NIST, NASA, Navy, and two DOE laboratories. The 1990s cases involved two USDA, NIST, Air Force, Navy, and three DOE laboratories.

B.1(d) Funding Combinations Remained Similar

In all of the successful 1980s and 1990s cases, the laboratories and companies used a variety of sources to fund technology development, technology transfer, product development, and commercialization. While funding sources included federal, state, international, and private sources, the federal laboratories and agencies financed the bulk of research and technology transfer; DOE was the only department with funding “issues.”²³ Also, virtually all of the successful cases involved private sector support for product development and commercialization in both large and small firms. CRADAs are assumed to be “funds-in” mechanisms, except in cases where where noted otherwise. Leveraged “outside” investments included venture capital funds or angel investments and agency SBIR funding and/or state technology program funding.²⁴

In addition to the federal support, in the 1980s group of cases: (1) The thermoplastic material case involved SBIR funding, state government funding, and company-supported product development. (2) The tracer technology involved a CRADA, consortia-supported demonstrations, international testing grants, and laboratory equipment sales. (3) The alginate-based herbicide/ pesticide case involved CRADAs and company-supported product development. (4) The chemically-imbedded herbicide/ pesticide case involved industry-paid work-for-others and company-supported product development.

In addition to federal funding, in the 1990s group of cases: (1) The laser-based case involved some university-supported consulting work. (2) The voice-coder case involved university funding contributions and outside capital for the spin-off firm. (3) The paper-quality tester involved company support of product development through the CRADA. (4) The microwave oven case involved SBIR funds and substantial venture capital investment. (5) The gravity meter case involved interagency transfers of funds and SBIR funds to develop a more compact instrument. Both spin-off companies in the gravity meter case received angel funding. The following cases relied on company-supported product development: the (6) light sticks, (7) Oatrim fat substitute, and (8) artificial-heart pump. In the latter two cases, millions of dollars

²³In both the 1980s and 1990s cases, federal funding cutbacks became an issue only in cases involving DOE laboratories. This was because of the uniqueness and competitiveness of the DOE R&D and CRADA funding system. Of the 1980s cases: (1) The scientist from the tracer technology case (at Brookhaven National Laboratory) indicated that laboratory user fees were a welcome revenue for the laboratory when it was experiencing downturns. (2) The team leader for the chemically-imbedded herbicide/pesticide (at PNNL) was frustrated with the DOE system and the lack of funding for his team to continue its development work. From the 1990s time frame: (1) In the microwave oven case (at Oak Ridge), the DOE Office of Industrial Technologies, a DOE headquarters program, supported the laboratory’s CRADA involvement when special DOE CRADA funds were no longer available. (2) In the artificial-heart case, the laboratory turned down private funding offered by one of the CRADA partners (Baxter Healthcare) because it was not sure how to handle “funds-in”; however, Baxter Healthcare and its hospital partner set up \$500,000 worth of equipment at the laboratory.

²⁴At least four of the small firms from both time frames (High Technology Services, Lambda Technologies, Micro-g, and Winters Electro-Optics) mentioned the issue of capitalization.

were invested by large multinational corporations, including ConAgra, A.E. Staley Manufacturing, Quaker Oats, Rhone-Poulenc, and Baxter Healthcare.

B.2 Mechanisms - Licenses, CRADAs Predominated in Both Periods

Licenses continued to be a traditional mechanism for transferring technologies in both the 1980s and 1990s cases. Although CRADAs were not possible legislatively during the early 1980s, eventually they became used in the 1980s cases. In the 1990s cases, CRADAs were the primary mechanism. No exchanges of technical personnel were uncovered in either time frame.

In the 1980s cases, the laboratories used the following technology transfer mechanisms -- besides information exchange, addressed in B.1(c) earlier:

- **Technology Licenses:** Licenses included two non-exclusive licenses for the thermoplastic material, and two exclusive licenses and one non-exclusive license as well as two sub-licenses for the chemically-imbedded herbicide/pesticide. The tracer technology, which involved a variety of mechanisms, included an exclusive license.
- **CRADAs:** In the alginate-based herbicide/pesticide case and the tracer technology case, the laboratories turned to CRADAs after they were legally possible.²⁵
- **Technical Assistance:** Two of the 1980s cases, the alginate-based herbicide/pesticide case and the radiation therapy case, involved technical assistance.
- **Reimbursable Work:** Even with five DOE cases spanning the two time frames, only one research team did “work for others.” This involved the 1980's chemically-imbedded material case at DOE/PNNL.
- **Scientific User Facilities:** The use of scientific equipment and facilities would be most likely to arise in the DOE-related cases because of their large and unique hardware. Only one case in the 1980s group, the tracer technology case, involved user facilities. Not surprisingly, it involved a DOE laboratory.
- **Standards Promotion:** The radiation therapy case involved proactive work by federal personnel with standards-setting communities to transfer calibration

²⁵The scientist from the alginate herbicide/pesticide case stated that laboratories were “practically giving away” intellectual property rights to companies under CRADAs. He added that while technology-transfer personnel were in favor of CRADAs, the laboratory inventors stood little to gain by them. The inventor of the penetrometer had some similarly negative views about CRADAs, commenting that CRADAs eased the technology transfer process, but made other laboratory activities more difficult.

technology and responsibility to “regional calibration laboratories.”

- **Procurement Contracts:** The penetrometer case involved two procurement contracts, one with a university to develop a prototype, and another with a company to develop six holotypes for use by the Navy. Also, the tracer technology involved a collaborative procurement project.
- **International Tests and Miscellaneous Mechanisms:** The tracer technology involved equipment loans and sales by the laboratory, joint public-private testing, and international tests or experiments. The scientist made many attempts to commercialize the instruments and services related to the tracer technology but was not successful.

In the 1990s cases, the laboratories used the following technology transfer mechanisms -- other than information exchange, addressed in B.1(c) earlier:

- **Technology Licenses:** License agreements included a license for the laser-illuminated method, a non-exclusive license for the microwave oven, three non-exclusive licenses (one of which evolved into a CRADA on a related technology) for the fat substitute, and two non-exclusive licenses for the light sticks.
- **CRADAs:** Five of the eight cases involved CRADAs and three of those involved more than one CRADA. These included the paper-quality tester, microwave oven, gravity meter,²⁶ fat substitute, and blood-flow diagnostics. The blood-flow diagnostics case provided the only example of an unusual CRADA configuration: two multiple-party CRADAs.
- **Technical Assistance:** One case in this group, the microwave furnace case, involved technical assistance.
- **Standards Promotion:** In the voice-coder case, the Air Force’s technical team funded the voice-coder technology which was actually researched in a university environment. The Air Force used unique technology marketing strategies in promoting the technology to national and international standards organizations.
- **Procurement Contracts:** The gravity-meter case involved a procurement

²⁶A company partner from the gravity-meter case noted that a CRADA was not necessarily profitable because there was no specific goal or deadline (unless structured a certain way). He said CRADAs were useful for ideas but not necessarily for commercial products. Further, a company partner couldn’t provide direction to the laboratory personnel involved in the CRADA; they could only access government information and ask specific questions. He said CRADAs are based upon the belief of both parties that useful, industry-oriented research would result from the CRADA effort. Yet, he said, companies don’t normally “do business” that way.

contract to develop the gravity meter for use by the Department of Commerce and eventually by the Department of Defense.

- **Cooperative Research:** The paper-quality tester case provided the only example of cooperative research in both sets of cases. The Forest Service granted cooperative research agreements so that outside organizations could test and evaluate the technology in a variety of settings.
- **International Tests:** The voice coder and artificial-heart diagnostics involved international testing.

Although CRADAs had been possible since the 1980s, laboratory scientists in two 1990s cases were just becoming familiar with them.²⁷ In the 1992 creation of the gravity meter, the chief scientist would have encouraged use of a CRADA rather than a procurement contract because it would have alleviated certain problems, but he didn't know about CRADAs. Eventually, however, NIST signed two CRADAs with the two firms spinning off from the original gravity-meter contractor. Similarly, the lead scientist for the light stick case said CRADAs were "talked about" when the technology licenses were being signed, but not commonly used at his laboratory.

The technology transfer mechanisms used in both the earlier and later time frames are summarized in Table F.²⁸

²⁷Technology transfer officers may have been aware of CRADAs as an option early on, but most agencies took years to adopt CRADA regulations; similarly, in the 1990s light stick case, restrictions on outside consulting created problems for one scientist. Although the issue was resolved and laboratory personnel can now consult, the scientist who raised the issue was unaware of it.

²⁸The cases, as numbered, represent the order of the cases as presented in Chapters III and IV.

TABLE F
TECHNOLOGY TRANSFER MECHANISMS USED

Pre-Legislation							Post-Legislation							
Cases	1	2	3	4	5	6	1	2	3	4	5	6	7	8
Licenses		x	x		x		x			x			x	x
CRADAs			x	x					x	x	x	x		x
Technical Assistance				x		x				x				
Personnel Exchanges														
Reimbursable Work					x									
User Facilities			x											
Standards Promotion						x		x						
Procurement Contracts	x		x								x			
Cooperative Research									x					
International Tests			x					x						x

B.3 User Benefits/Economic Impacts/Outcomes

The researchers and partners continued to describe success in many ways. They consistently used miscellaneous indicators and intangible measures.

B.3(a) Researchers, Partners Consistently Used Miscellaneous Indicators

Researchers in both the 1980s and 1990s cases used numerous miscellaneous indicators of outcomes and success other than the economic impact indicators discussed above in Section A. Most of these miscellaneous indicators were quantifiable or “semi-quantitative,” or at least measurable on a ranked scale if more than one data point were available. In the 1980s group of cases, the miscellaneous indicators included:

- **Increase in Market Share:** In the alginate-based herbicide/pesticide case, a company was producing three new alginate-based products. The company’s market share increased from approximately 25 to 85 percent based upon the

success of one of those products.

- **Number of Publications and Literature Citations:** In the alginate-based herbicide/pesticide case, the diffusion of information played a major role in transferring the technology. In the interview, the researcher suggested a formal scientific literature citation check as a way to understand the flow of information on that technology.
- **Gain of a Unique Patent Position:** M&T Chemical gained a unique patent position by licensing the thermoplastic material.
- **Number of Awards:** The radiation therapy standards program was put into place by a NIST researcher who received a number of awards for his work in that area.

In the 1990s group of cases, miscellaneous indicators included:

- **Taxes Paid by the Private Partners:** One of the companies in the gravity-meter case provided information on the amount of taxes paid by the company over the course of its several-year existence.
- **License Royalty Revenues:** The Navy laboratory provided information on the total amount of royalty revenues generated as a result of the two licenses on the light-stick technology.
- **New Market Opening:** The paper-quality testing technology opened up an unexpected new market for Isthmus Engineering in computer film-quality testing.
- **Level of Teamwork:** In the case of the microwave furnace, both the lead laboratory scientist and the company head commented on the importance of laboratory/ company relationships, citing this as a key to the company's commercial success. The company head said close interpersonal relationships and good communication with the laboratory scientists helped streamline the process of working with the laboratory generally. The lead scientist commented that the laboratory's business (technology transfer) and legal staff could do the CRADA paperwork, but not the necessary technical hand-holding and mentoring.
- **Speed-to-Market Advantage:** The Oatrim fat-substitute case provided an example of a company gaining a niche through unusually fast speed to the market.
- **User Satisfaction:** In the heart-flow diagnostics case, the hospital partner was extremely pleased with the CRADA work with the laboratory and with its access to equipment it wouldn't have been able to afford. One doctor praised the

inspired assistance and attitude of the laboratory researcher as key to the development of a superior heart pump. This is corroborated by the fact that the hospital and laboratory signed follow-on agreements. In the light stick case, both licensees indicated early on that they were pleased with their licensing arrangements, and one indicated a desire to work further with the laboratory.

- **Traded or Bartered Goods:** In the 1990s group, both the paper quality tester and gravity meter cases provided examples of commercial products being traded or bartered for intellectual property rights or consulting time. This type of data can be converted to dollar amounts and added to the statistics indicating commercial impact.
- **Commercial Space Occupied:** Two companies showed physical growth: Lambda Technologies expanded to an additional production floor site; Omniglow grew from 20,000 to 180,000 square feet in office and factory floor space.

B.3(b) Researchers, Partners Consistently Used Intangible Measures

Two cases in the 1980s group indicated quality-of-life improvements. Two cases in the 1990s group illustrated improvements in the laboratory or company image. Both of these indicators are intangible factors.

In the 1980s group: (1) The project leader on the chemically-based herbicide/pesticide emphasized the technology's ability to improve environmental conditions and to serve as an enabling technology for similar breakthroughs. (2) The tracer technology also contributed to a better quality of life through its environmental applications. (3) The radiation therapy quality assurance case referenced a contribution to safety and the avoidance of costs imposed by legal liability. However, in that case the benefits were indirect and consequently even more difficult to measure. A formal study of the impact of the radiation therapy quality assurance system confirmed its success. In that case, the transferred technology improved the nation's medical system rather than having a commercial impact. In cases where there are few or no (economically) measurable variables, official reviews become significant. Since that study, the quality assurance system's success had become so well-accepted that no additional studies have been commissioned.

In the 1990s group: (1) In the case involving the laser-based method, the laboratory experienced an improvement in its image as a result of the scientist's ground-breaking work in the "hot" biotechnology area of science. (2) In the gravity meter case, Axis Instruments showed that commercialization of the technology was possible, paving the way for two subsequent spinoffs which may not have been launched otherwise.

B.4 International Activity - Laboratories Remained Uninterested in Foreign Patent Rights

No laboratories applied for foreign patents either in the 1980s or 1990s cases, in spite of the increase in international activity and sales in the 1990s cases. However, there were instances in the 1990s cases when the scientist or the partnering firms sought foreign rights. In the 1990 case related to the Oatrim fat substitute, the scientist obtained foreign rights when the laboratory chose not to, and the partnering firms licensed and sub-licensed from him. Several of the partnering companies in the 1990s time frame sought foreign patents, including: (1) Digital Voice Systems Inc. from the voice coder case, (2) Lambda Technologies from the microwave oven case, and (3) Omniglow from the light stick case.²⁹

B.5 Economic Development, Technical Assistance - American-Owned Companies Predominated in Both Time Frames, But Did Not Use Available Services

In all of the cases, only two foreign-owned firms were involved in technology transfer, but they involved U.S.-based manufacturing. These firms were joint venture partners in the 1990s Oatrim case, but both had major manufacturing operations in the United States.

There appeared to be no connection between economic development programs and the American-owned firms involved in technology transfer in either the 1980s or 1990s cases. In neither time frame did the industry partners avail themselves of state, regional, or local economic development or technical assistance programs. One case in the 1980s time period, the thermoplastic material case, involved a small firm receiving state R&D funding, but no technical assistance or economic development services were granted.

Denver, Colorado ranks among the top four or five areas of the country in terms of entrepreneurial development. However, none of the small gravity-meter firms based there chose to be affiliated with any of the incubators or technology transfer networks. The president of one of the Denver area firms noted that economic development services and banking institutions were not that helpful. However, he said federal R&D funding programs were useful and referred to them as an “engine for the future.”

C. CHALLENGES TO THE TECHNOLOGY TRANSFER ENVIRONMENT

The findings also show conditions or changes that could be considered threats or challenges to the technology transfer environment, as follows:

1. **Roles of Other Laboratory Personnel** - The technology transfer function and research functions continued to register tension.

²⁹It is presumed that Agrifim International (from the 1980s chemically-imbedded herbicide/pesticide case) and Baxter Healthcare (from the 1990s heart pump case) also had foreign rights due to the extent of their international activities, although this was not mentioned.

2. **Barriers to Commercialization** - Private sector commercialization problems related to technology transfer increased, including scale-up problems, difficulties in marketing highly-technical products, and partnership problems.

C.1 Roles - Technology Transfer, Research Registered Tension

Throughout most of the cases in both time frames, a tension was “sensed” between the technology transfer function and the research function, which is not necessarily identifiable by specific data points from throughout the cases. As illustrations, in two of the 1990s cases, there was an effort on the part of the technology transfer personnel to maintain objectivity which was either explicitly or potentially an issue with researchers. This issue did not come up in the pre-legislation cases. (1) In the microwave oven case, the researchers commented that they were not included in legal negotiations on behalf of the technology and, as a result, the legal staff made commitments that the technical staff could not honor. (2) In the paper-quality tester case, the laboratory rotated its researchers periodically to keep them from becoming too attached to particular technologies and over promoting them.

C.2 Barriers - Private Sector Commercialization Problems Increased

In the 1990s cases, there was an increase in commercialization-related problems faced by the private sector partners (eg., production and marketing) that were not as evident in the 1980s cases. Most of these problems were fairly typical business problems that were accentuated by the highly-technical nature of the products.

Introducing highly-technical products to the market is especially difficult because they often require educational campaigns, making them more expensive to market than other new or mature products. In the 1980s cases, (1) the chemically-imbedded herbicide/ pesticide case illustrated the difficulty in marketing a product that necessitates a paradigm shift on the part of the customer from a short-term to a long-term orientation, and from the necessity for large quantities to only small quantities. Comments were also made about the difficulties for companies, particularly small firms, in achieving full-scale production of a highly technical new product and in purchasing expensive raw materials. Three of the 1980s cases involved these problems: the (2) thermoplastic material case, (3) alginate-based herbicide/pesticide case, and (4) chemically-imbedded herbicide-pesticide case. In the thermoplastic material case, High Technology Services manufactured and sold the material in sample-like quantities which did not allow volume discounts. When larger volumes were ordered, HTS negotiated a price and then contracted with a manufacturer to produce the material on a toll basis of two to five times the production costs, which did not provide much profit margin.

From the 1990s time frame, several cases highlighted the problem of new products with no initial demand, and for which the market had to be created and customers educated. These were: (1) the voice coder, (2) paper quality tester, (3) gravity meter, and (4) the Oatrim fat

substitute cases. The voice coder, in particular, was very different technologically from existing products. In response to these marketing difficulties, the partnering companies relied on their reputation and networking within their own technical communities to obtain business. For example, the company commercializing the paper quality tester, Isthmus Engineering, relied on word-of-mouth to spread its reputation for quality products. Axis Instruments, the original gravity-meter partner that went out of business, had emphasized formal publicity; in contrast, the successful Axis spin-off company relied more upon contacts within the international technical community.³⁰ Two 1990s cases also encountered scaling-up problems: (5) the gravity meter and (6) fat substitute cases. In the gravity meter case, the smaller of the two spin-off companies had to “go outside” for machining work because it did not have its own machine shop. Large corporations also experienced problems in scaling up. The large companies in the Oatrim fat substitute case said they should have been more aware they were receiving only laboratory samples from USDA. They discovered that production in larger quantities resulted in an essentially different product. Furthermore, in the 1990s group of cases, in the (7) fat substitute case, the laboratory’s licensees, being partnerships and joint venture arrangements, faced the management challenges inherent to these types of arrangements. According to the company representatives, such partnerships were easy to conceive but hard to manage because they involved merging different business cultures and personnel nationalities.³¹

SUMMARY

Table G, “Similarities and Differences Between the Two Time Frames,” summarizes the details contained in this chapter. (Not all of the findings listed in the table were discussed in the text above.) The next chapter summarizes the key findings and presents implications and conclusions.

³⁰This company was also faced with a nearly saturated market for its highly specialized instrument, and with competition from well-funded foreign government agencies producing gravity meters and having greater access to international markets. It was infeasible for the company to use overseas agents because of their lack of familiarity with its highly technical product.

³¹This made decision-making difficult and fraught with the risk of alienation and ultimately failure.

TABLE G

**SIMILARITIES AND DIFFERENCES
BETWEEN THE TWO TIME FRAMES**

Topic	Pre-1986 Act	Post-1986 Act
Roles of Laboratory Researchers and Other Personnel	<p>Laboratory prototyping not done; some sampling</p> <p>Champion role by laboratory researchers focused on technology marketing, demonstrations, etc.</p> <p>Laboratory researchers not risk-adverse, but generally careful approach to tech transfer</p> <p>Laboratories uneasy with market and technology assessments</p> <p>Technology transfer and research functions had subtle tension</p>	<p>Laboratory prototyping and samples on the rise</p> <p>“Champion” role focused on interaction with CRADA partners</p> <p>Pockets of cautiousness still exist, depending upon laboratory culture</p> <p>Inexperience with market and technology assessments continues</p> <p>Technology transfer and research functions registered tension</p>
Technologies and Applications	Incremental improvements and evolutionary technology applications	More revolutionary applications occurred
University Involvement	Joint government/university inventing prevails at the bench scientist level	Joint government/university inventing results from inter-institutional ventures
Funding, Financing	Combination of funds used to support technology transfer and commercialization; CRADA funding issues only apparent in DOE cases	Combination of funds used to support technology transfer and commercialization; CRADA funding issues only apparent in DOE cases
Intellectual Property	<p>More emphasis on scientific publishing, less emphasis on patenting</p> <p>Royalty-sharing incentives are very important to the laboratory inventors</p> <p>Lack of incentives to patent; researchers less “patent-savvy”</p> <p>Inventing partners = universities</p>	<p>More aggressive patenting by both laboratories and partnering companies</p> <p>Royalty-sharing incentives are even more important to the laboratory inventors</p> <p>Similar lack of incentives (earlier-on); lack of patenting incentives eventually subsided</p> <p>Inventing partners = companies</p>
Technology Transfer Mechanisms	<p>Scientific journals are standard for the scientific community</p> <p>Licenses a more traditional mechanism, although it took a long time to gain</p>	<p>Scientific journals still important</p> <p>Licenses widely used, with only minor issues unresolved; CRADAs prevail as a</p>

	<p>expertise in their implementation; CRADAs not legislatively possible; when made possible, laboratories turned to them</p> <p>Some researchers have negative perceptions of CRADAs</p>	<p>mechanism after long-term unfamiliarity</p> <p>Some company partners have negative perceptions of CRADAs</p>
User Groups, Laboratory Partners	<p>Small firm involvement in technology transfer not as prominent</p> <p>Technology push; user contacts initiated by laboratory researchers</p> <p>Earlier-stage technologies, less market-orientation, broad-based user groups</p>	<p>More small firm involvement in technology transfer</p> <p>Market pull; contacts were user-initiated</p> <p>Targeted user groups and markets</p>
Barriers to Commercialization	<p>Failures: two products stopped short of commercial marketplace; five licenses inactive, although three products resulted</p> <p>Scaling-up difficulties (particularly small firms)</p>	<p>Failures: one inactive license; one failed line of products (although several of these products taken over by a new company)</p> <p>Scaling-up difficulties, difficulties in marketing highly-technical products, and joint venture and partnership problems among companies</p>
Other Factors	No involvement of foreign firms in technology transfer	Foreign-owned firms were involved, but with U.S.-based manufacturing
User Benefits/ Economic Impacts/ Outcomes	<p>16 products resulted from the technologies in the cases; “\$ few thousand” in sales revenues; no spinoff start-ups resulted; no other sales or employment data made available</p> <p>Variety of miscellaneous and intangible indicators used to describe success</p>	<p>114 products resulted from the technologies in the cases; \$7.7 million sales revenues; six spinoff start-ups resulted; 348 <u>net</u> jobs generated</p> <p>Variety of miscellaneous and intangible indicators used</p>
International Activity	<p>Moderate international sales</p> <p>No laboratories applied for foreign patents</p>	<p>More extensive international sales</p> <p>No laboratories applied for foreign patents; inventors and partnering firms exercised foreign rights</p>
Government Gains	Unanticipated government benefits, dual uses, and spinbacks apparent	Unanticipated government benefits, dual uses, and spinbacks apparent
Economic Development, Technical Assistance	No connection between economic development programs and technology transfer	No connection between economic development programs and technology transfer
Elapsed Time	15 to 20-year development time	8 to 10 years up to commercialization