BEST PRACTICES IN SCIENCE AND TECHNOLOGY-BASED ECONOMIC DEVELOPMENT POLICY:

U.S. AND GLOBAL

Document 2

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U.S. AND GLOBAL

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North Carolina: Leadership in Innovation

North Carolina's historical leadership in S&T-oriented policies for economic development:

- *Research Triangle Park*
- *MCNC*
- *N.C. Biotechnology Center*
- *first statewide digital network*
- *information highway*
- *Centennial Campus*
- *16 campus consolidated university system*
- *37 private colleges and universities, including Duke and Wake Forest*
- *59 community colleges, all within 30 miles of students*
- *N.C. School of Science and Math*

In many regards, North Carolina has been a leader in the development of science and technology (S&T)-oriented policies to further economic development. Research Triangle Park, created in 1959 with the leadership of prominent state citizens, is recognized internationally as one of the earliest and most successful examples of an R&D-oriented business complex. Similarly, North Carolina was among the first states to develop technology centers, in biotechnology, in 1979, and in microelectronics in 1980 (since renamed MCNC with a broader technology focus). Also in the early 1980s, North Carolina pioneered the first digital statewide network, and in 1993 partnered with private telecommunications companies to deploy the world's first state (or national) broadband network, the North Carolina Information Highway (see inset on page 9). In more recent years, North Carolina State University has opened Centennial Campus – an innovative effort to bring together university- and industry-based scientists and engineers around the development of new processes and products in fast-emerging technology areas. And, the state has been at the forefront of information highway development, in partnership with private telecommunications companies.

North Carolina also has been a leader over the past thirty years in post-secondary education. The sixteen campus University of North Carolina system is among the largest consolidated networks in the country. The two research I universities in the system -- UNC-Chapel Hill and North Carolina State University -- consistently rank among the top public institutions in the U.S., in objective studies by the National Research Council and the National Science Foundation. The UNC system also is among the most-heavily state-supported in the U.S. Private universities also play an important role in the research and development system in North Carolina, exemplified by the major research activities at both

Duke and Wake Forest Universities. North Carolina's fifty-nine community colleges represent one of the largest state-run community/technical college systems in the United States, enrolling almost 780,000 students – none of whom are located more than 30 miles from a campus or satellite location. Even at the high school level, North Carolina innovated in 1978 with the creation of the North Carolina School of Science and Math – not only to train the brightest young minds in the state, but also, to take a leadership role in the development of innovative teaching methods and curricular material.

Overall economic performance has been strong in North Carolina.

These efforts have made a difference in North Carolina. Since the 1950s, we have undergone a major transition from an economy based on agriculture and traditional manufacturing, to one with a healthier mix of activities, including a growing presence of pharmaceuticals and biotech, telecommunications, environmental science, chemical products, and more diversified production. The rate of new business formation and expansions has been consistently high, and the overall rate of unemployment has been among the lowest in the U.S.

COMPETING STATES AND REGIONS DO NOT STAND STILL

The Progressive Policy Institute's categories of indicators used to rank states' place in the "new economy," and NC's rank:

- ***Knowledge jobs***: jobs in offices and held by managers, professionals, and technicians; the educational attainment of the workforce. [NC: 31]
- ***Globalization***: foreign direct investment and the export orientation of manufacturing. [NC: 8]
- ***Economic dynamism and competition***: jobs in "gazelle" companies (having sales growth of 20 percent or more for four straight years); the rate

In the past decade or so, other states in the U.S. and countries around the world have begun to recognize the importance of science and technology as an engine of economic growth. They have begun to invest heavily in their own programs -- indeed, moreso than North Carolina has in many instances -- and now vie for leadership in several critical areas.

As we approach the 21st century, we need to take a realistic view of our state's policy efforts in S&T, within the context of an increasingly active set of competitors. Consider, for example, a recent study by the Progress and Freedom Foundation which placed North Carolina twenty-eighth among the states in technology implementation. In February 1999, of economic “churn” (combining new business start-ups and existing business failures); and the value of IPOs by companies. [NC: 32]

- ***The transformation to a digital economy***: the percentage of adults online; the number of “.com” domain name registrations; technology in schools; and the degree to which state and local governments use information technologies to deliver services. [NC: 39]
- ***Technological innovation capacity***: the number of high-tech jobs, scientists and engineers in the workforce, patents issued; industry investment in R&D; and venture capital activity. [NC: 24]

Experts consider Utah, Georgia, and Pennsylvania to be interesting case studies because of their use of pro-active and innovative S&T policies to foster economic development. Those experts also cite Singapore and Israel as policy innovators.

Governing magazine gave North Carolina a “C” grade in information technology. And in July 1999, the Progressive Policy Institute ranked North Carolina thirtieth among the states in its “readiness” to compete in the “new economy” of the 21st century. The methodology for that ranking is complicated, but generally combines states’ scores in the five categories shown in the left panel. The PPI explained our state’s ranking in the following way:

> *Given some states’ reputations as technology-based, New Economy states, their scores seem surprising at first. For example, . . . North Carolina rank[s] 30th . . . , in spite of the fact that the region around Research Triangle Park . . . boast[s] top universities, a highly educated workforce, cutting-edge technology companies, and global connections. . . .* ***However, the parts of the state outside the metropolitan region are more rooted in the old economy—with more jobs in traditional manufacturing, agriculture, and lower-skilled services; a less educated workforce; and a less developed innovation infrastructure.*** *As this example reveals, most state economies are in fact a composite of many regional economies that differ in the degree to which they have adapted to the New Economy.*

The leaders in the PPI study include Massachusetts (first) – a highly urban state with a large Route 128-Cambridge high-tech complex – and California (second) – which contains several large metro areas, Silicon Valley, and a legacy of high-tech defense contracting. Three other states that rank above North Carolina – Utah (sixth), Georgia (twenty-fifth), and Pennsylvania (twenty-sixth) – are interesting because of pro-active initiatives in recent years. Singapore and Israel are also viewed as policy innovators.

Bridging Theory and Practice

The four technology policy approaches we discuss have a solid theoretical foundation. Scholarly work on "endogenous growth theory" stresses the importance of human capital, R&D and technology development in economic growth (Romer, 1986, 1990; Lucas, 1988; Grossman and Helpman, 1991a, 1991b; Aghion and Howitt, 1992; Ochoa, 1996; and more). The major tenets of the theory are that:

- R&D activities create increasing returns to scale, making sustained long-run economic growth possible through externalities created by technology diffusion. That supports high-tech company formation and R&D activities.
- Technology diffusion is facilitated by the interconnection among technicians, researchers and entrepreneurs. That requires information technology and university-industry partnerships.
- Human capital is a critical element in the production of new knowledge (technology), which justifies investments in human capital.

Another approach, "pipeline theory," views development as a sequence of acts, from R&D to production and marketing, each with spatial implications (Brooks, 1994; Gomory, 1989). R&D is presumed to change a region's level of wealth by affecting production processes of local industries (more R&D leads to more innovation). The implication is that government should support more R&D.

LEARNING FROM BEST PRACTICES:
LESSONS FROM UTAH, GEORGIA, PENNSYLVANIA, SINGAPORE, AND ISRAEL

The five full case studies are attached as appendices. The innovative activities fall into the four categories of policies shown in Table 1. Those policy approaches are well-grounded in theory (see inset on previous page). Table 2 summarizes the strategies employed by each of the case study governments.

TABLE 1: Four Approaches to S&T Policy Used by Case Study Governments

Supporting high tech companies and facilitating R&D activities

Theory and evidence support the belief that innovative high tech companies can serve as engines of economic growth and enhance a region's global competitiveness. That has led the case study governments to develop various financial, technical, and legal programs to make high tech businesses more viable, and to induce more R&D.

Facilitating university-industry partnerships and commercialization

The profiled regions have developed many programs designed to bring research from university labs to the marketplace. Those programs provide financial support for the commercialization of university research and create vehicles to facilitate interaction between universities and industries.

Investing in human capital

Sustained long-run economic growth requires technological transformation and structural change. The leading technology regions are investing heavily in programs to enable the workforce to learn and re-learn the competencies and skills required in that dynamic economic world. That includes, for example, basic literacy, including a working knowledge of science and math, lifelong and distance learning, displaced workers programs, and incentives to increase interest in science and engineering fields.

Harnessing information technology

A region must have a well-developed, well-utilized information network to be competitive in the knowledge economy. The leading technology regions are investing substantially to develop information networks linking schools, governments, private companies, and other organizations, allowing their citizens to access an ever-expanding amount of information.

Table 2: Summary of the Five Regions' Activities, by Type of Approach

Approach	Region	Activities
Supporting high tech companies; encouraging R&D	Georgia	Provide financial, technical, and management services for high tech startup companies
	Pennsylvania	Provide financial and technical support for high tech startup companies; Help existing companies to adopt new technologies; Provide R&D tax incentives
	Utah	Provide loans for small high-tech businesses; Help small companies to develop and commercialize new products and services
	Israel	Provide financial support for academic and industrial R&D; Develop international R&D cooperation; Develop R&D database and supercomputing center
	Singapore	Upgrade science and technology infrastructure to stimulate R&D activities; Provide financial support for R&D activities; Provide seed funds for startup companies
Facilitating university-industry partnerships and commercialization of new products	Georgia	Create a seed capital fund to support innovative and marketable university research
	Pennsylvania	Provide financial and technical assistance for the commercialization of new technology
	Utah	Provide funds for the commercialization of university research; Promote alliances between universities and technology-oriented businesses
	Israel	Develop science-based industrial parks near universities; Provide technology incubators for innovative entrepreneurs
	Singapore	Provide financial support for inventors to bring their innovations to market; Facilitate social activities among innovators, researchers, and entrepreneurs

(Continued next page)

Table 2: Summary of the Five Regions' Activities, by Type of Approach

Approach	Region	Activities
Investing in human capital	Georgia	Network public schools and libraries through an education network
	Pennsylvania	Provide financial and technical support for workforce training
	Utah	Develop a statewide education network; Educate citizens to be Internet-ready and technologically smart
	Israel	Upgrade the teaching of mathematics, science and technology; Develop scientific literacy among children and adolescents
	Singapore	Provide funds to train scientists and engineers; Recruit international R&D workforce; Provide scholarships for promising young students in IT-related fields
Harnessing information technology	Georgia	Develop GIS data clearinghouse; Develop data warehouse standards; Develop Internet standards; Enact Electronic Records and Signatures Act; Develop an education network
	Pennsylvania	Develop fiber optic network; Develop statewide IntraNET; Interconnect classrooms to build a statewide education network; Develop Technology Atlas of technological resources
	Utah	Develop a statewide education network; Develop a strategic blueprint for the utilization of IT resources
	Israel	Develop supercomputing center
	Singapore	Develop nationwide high-speed fiber optic information infrastructure linking home, school, and office; Provide funds to facilitate the development of pioneering IT products/services

IMPLICATIONS FOR NORTH CAROLINA

The case studies summarized above and presented in the appendix suggest some actions for policy makers in North Carolina to consider as part of the state's mix of S&T programs. We discuss these below, following the structure of Tables 1 and 2.

Support and facilitate R&D activities: One striking similarity among leading technology regions is their use of programs to promote R&D by their businesses and universities. We learned recently that Michigan, for example, is devoting a large share of its tobacco settlement money to universities for research purposes. North Carolina's R&D intensity (measured by the ratio of total R&D expenditures to gross state product) is 1.3 percent, compared to 2.7 percent for the U.S. and even higher ratios for states like Massachusetts and California. **To be competitive in the knowledge economy of the 21st century, North Carolina's R&D--not only by its universities, but also by its industry--must be at or above the U.S. average.** The William S. Lee Tax Act includes tax credits for R&D expenditures by industry, but there is some sentiment among business leaders that those are not sufficient.

Facilitate interactions between universities and industries: There is ample evidence that knowledge-based industries tend to locate near appropriate knowledge resources (such as research universities). In short, proximity provides opportunities for interaction among researchers, technicians, and engineers, which facilitates both the creation and diffusion of knowledge. North Carolina has developed technology strength in several areas, built around university-industry partnerships, notably in electronics, life science, chemicals, and environmental science.

However, much of the collaborative activity is concentrated in one region--Research Triangle--which has three top-ranked research universities and a mix of 500 businesses. Additional efforts need to be made to expand those productive interactions outside the Triangle, by connecting other UNC campuses with their local businesses, and those campuses and the businesses with the Triangle's universities. The bioscience incubator at Eastern Carolina University, the Piedmont Triad Research Park, and the Cameron Applied Research Center at UNC-Charlotte are good examples of such activity in other parts of the state.

The North Carolina Information Highway *(NCIH) was developed as a public-private partnership between the telecommunications industry and state government. The partnership resulted in the first large-scale deployment of an ATM-Sonet (or broadband) network in the world. Private telephone companies provided and own the telecommunications infrastructure. The state supplied the global vision and policy coordination, and serves as the major user, running voice, video and data over the system. Public schools, community colleges, universities, hospitals, prisons and government facilities have first priority in accessing the NCIH.*

Currently, there are more than 18,000 wide area networks -- each capable of serving more than 1,000 users -- that utilize the NCIH for data, and there are more than 170 interactive video sites. Internet connectivity is provided to the schools by running the IP network across the ATM backbone.

All across North Carolina from Murphy to Manteo, the NCIH has opened up North Carolina rural communities to broadband connectivity. That has implications for higher quality and more uniform education ("distance learning") and health care ("telehealth"). Rural connectivity has been a major policy focus of the Governor's office, the Board of Science and Technology, the N.C. Rural Center, the

Create an environment conducive to high-tech start-up companies: Innovative, high tech start-ups also serve as an engine of new technology development. Therefore, creating an environment conducive to those companies is crucial for improving North Carolina's technological competitiveness and consequent future growth. North Carolina already has spawned high profile start-ups, including SAS, Sphinx, Emrex, Quintiles, and Red Hat, some on the strength of the research universities. But to be more entrepreneurial, the state needs more than intellectual capital; it needs more venture money, more technical assistance, more incubator space, more spinoffs in rural areas, and better publicity of successes.

Invest in human capital: The most important resource in the 21st century knowledge society will be human. That may be the biggest hurdle for North Carolina to be a leader again in science and technology. According to the National Assessment of Educational Process, which is administrated by the U.S. Department of Education, the average proficiency in math and science of eighth grade North Carolina students ranked twenty-fourth and twenty-third, respectively, out of 40 states in 1996. The percentage of high school completion ranked thirty-seventh, and spending per pupil in 1996 ranked thirty-ninth among 50 states (Hovey and Hovey, 1998). For its workers to be competitive in the fast-moving economy of the 21st century, North Carolina must devote more thought and resources to its human capital needs.

Invest in information infrastructure: Although North Carolina's information highway was a

Department of Commerce, and most recently, the Rural Prosperity Task Force. A pilot project -- Connect NC -- is underway in western North Carolina. The objective there -- and later in other regions of the state -- is to make the first mile of connectivity more accessible and affordable to rural families, governments and businesses.

pioneering effort in the early 1990s, other regions are investing more heavily now in information infrastructure: to wit, the Singapore One and Pennsylvania Link to Learn projects that are connecting homes, offices, schools, and government offices. And Texas recently embarked on a massive investment program of nearly $40 billion over several years.

Information infrastructure also has been at the heart of breakthroughs in the biosciences industry. Major advances in genomics research have been jump-started by information technologies.

To attract and build businesses that rely on connectivity and produce the connectivity hardware, and to make existing businesses and residents more productive, the state needs to renew its commitment to information technology.

Appendix

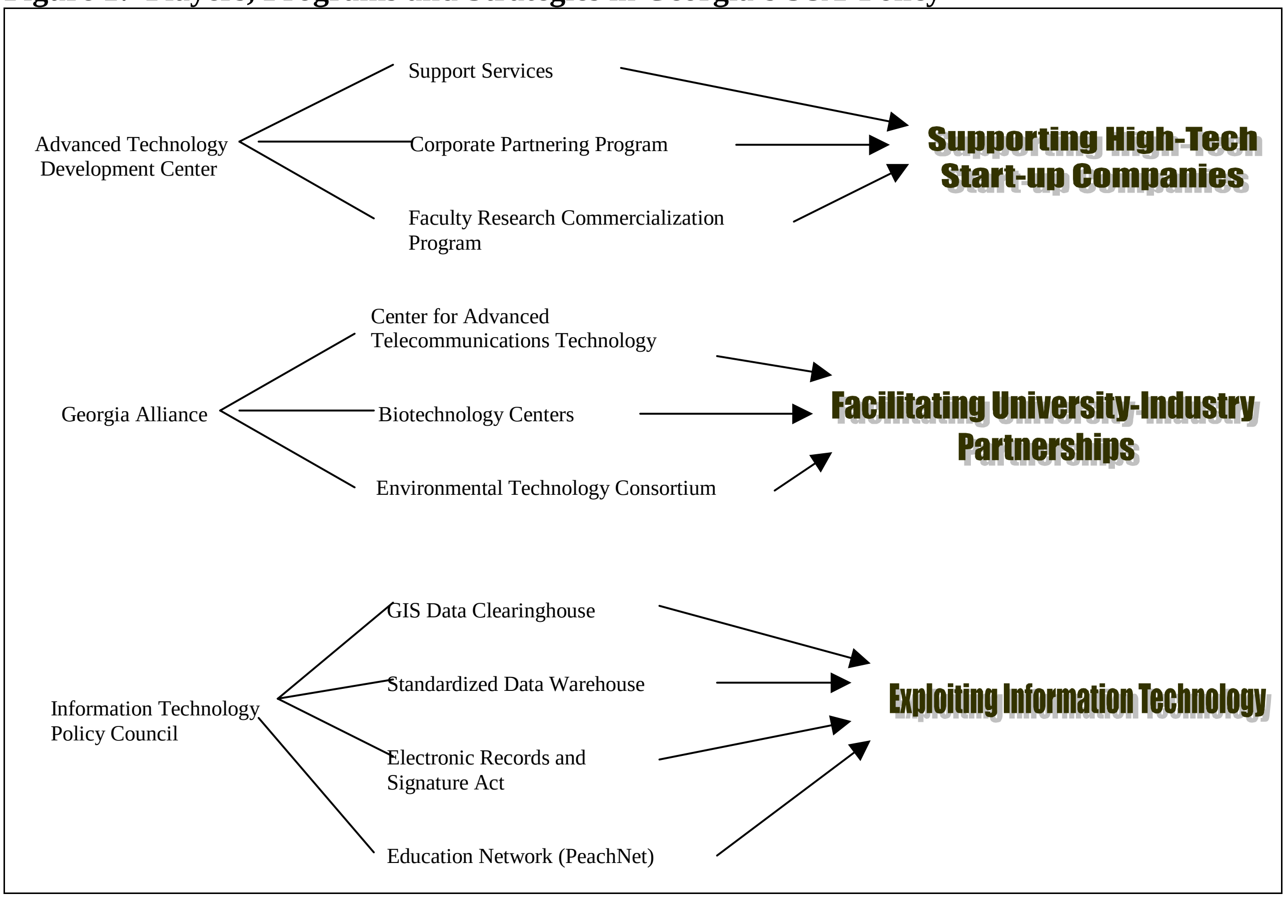
Case Study Profiles of:

Georgia
Pennsylvania
Utah
Israel
Singapore

Profile #1: Georgia

Georgia ranks tenth in population and 13th in gross state product in the U.S. The composition of the state's economy is similar to that of the nation as a whole; manufacturing is the largest sector (19%). However, Georgia has paid special attention to the state's R&D capability. In 1995, Georgia ranked fifth nationally in the average per capita R&D investment and sixth in the total R&D investment. In addition, Georgia is one of only three states where R&D as a percentage of total state spending exceeds one percent.

Figure 1: Players, Programs and Strategies in Georgia's S&T Policy



Players

Like many other U.S. states, Georgia's institutional structure for science and technology policy is relatively decentralized. There are several players in state government as well as in independent consortia and universities; four players are prominent among them.

- The **Governor's Advisory Council on Science and Technology Development**, established in 1992, served as a major science and technology policy developer and a promoter of the role of technology in the economic development of the state.

- In 1995, the state created the **Information Technology Policy Council** (ITPC) to focus more on the development of information technology and its utilization.

- The **Economic Development Institute** (EDI) is another major player in economic development, technology transfer, and enterprise development. EDI, headquartered at Georgia Tech, has 13 regional offices as of 1996 and is still expanding.

- Lastly, the **Georgia Research Alliance** is a nonprofit organization representing a three-sector partnership of state government, the business community, and research universities. The organization's mission is to foster well-developed university-industry partnerships that leverage research capability to enhance the economic development of the state.

Strategies

As Figure 1 illustrates, Georgia has focused on three major strategies in developing its science and technology policy: supporting high-tech startup companies, facilitating university-industry partnerships, and exploiting information technology.

Supporting High-Tech Startup Companies

EDI has developed and implemented various technology development programs, notably the Advanced Technology Development Center (ATDC). ATDC is seen as the most important organization in Georgia in science and technology policy. Created in 1980 as a branch of EDI, ATDC has played an important role as a catalyst for high-tech startup development and university-industry partnerships. The center provides technical and management services through three types of programs targeted to high-tech startup companies:

- **Support Services**: ATDC provides assistance with strategic planning, financing, and marketing to high-tech startup companies accepted into the program. Once accepted, each company is assigned an ATDC business management consultant to advise and monitor the company's performance.

- **Corporate Partnering Program**: ATDC helps to identify potential corporate partnerships between small and larger companies. Smaller companies can learn and benefit from larger ones, and large companies are often more efficient and successful when they can rely on small companies to develop new technology products and services. Since its establishment in 1993, this program has matched many startups with medium-sized existing companies to create successful partnerships.

- **Faculty Research Commercialization Program**: ATDC provides financial and business development support to help faculty commercialize new technological innovations in laboratories. The goal of the program is encourage academic researchers who are developing a new technology to establish a new company. In 1994, the program spent $197,000 and supported five projects.

Facilitating University-Industry Partnerships

The partnership orientation of Georgia's science and technology policy is well reflected in the Georgia Research Alliance. Founded in 1990 by the business community, the Alliance has facilitated a partnership among research universities, business leaders, and state government. The goals of the organization are to leverage university research, to assist technology-based industries, and to bridge academics and industry. From 1993 to 1995, Georgia distributed $58 million through the program to six member universities. Program funds, raised from both state and private sector, are growing rapidly. The Alliance has also created a seed capital fund to support innovative new research in environmental technologies, new telecommunications, and biotechnology. Operating centers have formulated research projects around these concentrations to stimulate cross-disciplinary and cross-institutional research.

- **The Georgia Center for Advanced Telecommunications Technology** (GCATT) supports university researchers and startup firms in the telecommunications industry. The organization also conducts basic research in telecommunication technologies.

- **The Georgia Biotechnology Centers** (GBC) support research programs in biotechnology areas including genetics and molecular medicine, vaccine and diagnostics development, and drug design and synthesis.

- **The Georgia Environmental Technology Consortium** (GETC) provides direct support for environmental scientists and engineers of Georgia and fosters partnerships among those professionals in universities, industry, and government.

Exploiting Information Technology

One of Georgia's major strengths as an elite technology region is its information technology policy. The Information Technology Policy Council (ITPC) is responsible for much of Georgia's policy initiative in developing and utilizing information technology; for example:

- Georgia has established a geographic information system (GIS) data clearinghouse and is developing a comprehensive statewide **GIS system** to provide an information resource for more efficient and effective planning and budgeting.

- Recognizing the lack of data sharing among state agencies, Georgia developed system standards for all **data warehouses** within Georgia for more efficient data management and data utilization. Based on a new concept of data custodianship rather than ownership, the State is trying to make state government information more easily accessible, subject to the statutory limitations of confidentiality.

- ITPC is developing **Internet standards** for state agencies and is coordinating Internet activities to offer government services 24 hours and seven days a week to the public.

- Georgia is one of the leading states in using **electronic signatures**. The state established a legal framework for electronic signature in 1997. The Electronic Records and Signatures Act authorized the use of electronic signatures and provides the legal underpinnings. The Act also encouraged public and private organizations to use electronic media to conduct their business. Currently, the State is working to enhance security capabilities for electronic records and electronic signatures.

- Georgia has developed an **education network**, PeachNet, supporting connectivity among all public educational institutions and libraries within the state. ITPC plans to expand and integrate current PeachNet into high bandwidth initiatives, referred to as the GigaPoP and Southern Crossroads Projects.

Profile #2: Pennsylvania

Pennsylvania is one of the largest states in the nation, ranking fifth in both population and the gross state product. The composition of its economy is close to the nation's as a whole. As the home of electricity, computer, and the Internet, Pennsylvania has a strong high-tech heritage. Many biotechnological breakthroughs, such as the first polio vaccine, also emerged in Pennsylvania laboratories. Figure 2 shows some of the impressive facts about this state.

Despite its rich history of technological breakthroughs, Pennsylvania's economy was driven by traditional smokestack manufacturing industries until 20 years ago. After being hard hit by recession in the early 1980s, Pennsylvania took a new approach to economic development by launching efforts to strengthen its position in technology-intensive industries. When its major manufacturing sectors (electrical machinery and needle trades), which comprised about 36% of the state's manufacturing employment, lost 68% of their jobs due to the recession, the Pennsylvania MILRITE Council, a state level organization of business, labor, and government leaders, began to discuss possible strategies for state economic development policy.

Figure 2: Facts about Pennsylvania's Science and Technology Presence

1 of 8 **Biotechnology firms** in the U.S. are located in Pennsylvania.

Pennsylvania is the 2nd in the nation in terms of **pharmaceutical employment**.

Pennsylvania ranks 4th in the nation in terms of the number of **research and development facilities**.

Pennsylvania is the 4th in the nation in terms of **doctoral scientists and engineers**.

There are nearly 40 **Nobel Prize Winners** at research institutions in the Philadelphia region.

Source: Technology 21 Web Page: www.state.pa.us/PA_Exec/DCED/tech21/

Players

Two major features are at the heart of Pennsylvania's science and technology policy: 1) a well-developed technology development program referred to as the Ben Franklin Partnership Program; and 2) a well-developed and highly utilized statewide information network. The 15-member Ben Franklin/Industrial Resource Centers Partnership Board is responsible for the Ben Franklin Partnership Program. The Governor's Office of Administration/Office for Information Technology (OIT) oversees the development of information networks across the state.

Strategies

Pennsylvania has focused on two major strategies in developing its science and technology policy: 1) supporting technology development and utilization; and 2) exploiting information technology.

Supporting Technology Development and Utilization

Ben Franklin Partnership Program: The mainstream economic thought in the early 1980s, so-called Reaganomics, focused on market mechanisms and limited government. Following this policy direction, the Republican Thornburgh administration and legislative members of the MILRITE Council introduced the Advanced Technology Job Creation Act. It aimed at promoting the development of advanced technology and assisting emerging high-tech companies as a way to create a business environment conducive to private-sector companies. This approach allowed the government to minimize its direct involvement and to use resource pooling rather than relying solely on public appropriations. This legislation became the foundation of the Ben Franklin Partnership Program, introduced with the belief that the state government could support small technology start-ups and facilitate the cooperation between industries and universities to help solve firms' problems. It was the first technology-driven economic development program of this kind in the nation. The program was designed to provide financial support for early-stage, high-tech venture companies and R&D activities and to stimulate the transfer of technology, commercialization of research, and integration of advanced technology into mature industries.

The program is implemented around four **Ben Franklin Technology Centers** (BFTCs), which are located in Pittsburgh, Bethlehem, Philadelphia, and University Park. They serve as business partners to manufacturing and high-tech industries in Pennsylvania. As independently operated nonprofit organizations, BFTCs provide financial and technical assistance for new technology ventures, new product development projects, technology commercialization, and workforce training. However, the focus of funding varies widely among the four centers. For example, one center spends over 70 percent of its funding for technology development activities, while at another center, more money goes toward product and process development. The highly decentralized and independent organizational structure allows each center to be responsive to the specific economic development needs of the region it serves. There are two major technology development programs administrated by BFTCs.

- **Seed Venture Capital** was established in 1984 to finance early-stage startup companies in Pennsylvania. The creation of the fund was prompted by several studies in 1982 and 1983 confirming the shortage of venture capital in Pennsylvania. The reason for the shortage was simply unavailability of funds due to conservative banking practices in Pennsylvania. The private sector capital market could not provide enough funding for early stage start-up companies, and Seed Venture Capital was created in response to this gap. The funds provide equity and other types of financial support to startups, which must raise 3:1 matching funds. These funds distributed up to $50 million to over 40 companies until the early 1990s.

- **Challenge Grant** was designed to provide financial support for small businesses seeking to develop a new technology or a new product. Typically the grant ranges from $5,000 to $100,000 and often has a royalty payback provision.

Industrial Resource Center (IRC) program was founded in 1988 to help companies to adopt proven technologies to increase their competitiveness. Composed of eight private and nonprofit economic development corporations, IRC provides financial and technical support to Pennsylvania's manufacturers to improve their technologies and operations. The roles of IRC and BFTC complement each other: IRC services are focused on short-term projects that utilize existing technologies, while BFTC focuses on longer-term technology development projects.

R&D Tax Incentives: Pennsylvania has taken aggressive steps, including providing tax benefits for high-tech industry, to stimulate R&D activities and technological innovations. The state offers employers a 10 percent tax credit for new R&D investments and provides a $1,000 tax credit per newly created job for companies that focus on the development of technology. Pennsylvania also eliminated its 6 percent computer service sales tax to encourage companies to invest more in computer-related technology.

Plans for the Next Century: Pennsylvania's biggest concern for the future is how to be a high-tech leader in the 21st century. The Commonwealth's vision and its strategic planning for the next century are described in the recently published *Technology 21 Initiative Report*. The initiative was developed to seek industry input regarding the role of state government in helping Pennsylvania high-tech businesses remain competitive. The major recommendations of the committee were as follows:

- Develop a technology-focused marketing to promote state's image as a high-tech state
- Attract or expand anchor firms that serve as the primary catalyst for a technology-intensive economy
- Establish a public/private joint fund that enables young high-tech firms to become engines of growth
- Seek opportunities to make Pennsylvania a laboratory for the next generation of technology, particularly information technology service and products
- Develop a system to supply technically knowledgeable and skilled workers
- Establish a true technology-intensive business climate
- Establish a research and technology network among research institutions, universities, and industries

Exploiting Information Technology

Pennsylvania has demonstrated its awareness of the importance of information technology by implementing aggressive information technology programs. The intensive utilization of information technology has made a significant contribution to strengthening the competitiveness of Pennsylvania's economy. For example, a proactive public-private partnership referred to as Team Pennsylvania developed the **Business Resource Network**. This is a statewide information network providing an efficient and effective access to Pennsylvania's business assets, business assistance programs, education system, and any other information on Pennsylvania that might be helpful for a business. The OA/OIT have played an important role in statewide information network development. The most noticeable efforts of the OIT are found in the development of statewide information networks and database systems. Some examples of those efforts are as follows.

- The OIT initiated a high-speed **fiber-optic network** development plan (Metropolitan Area Network) in 1993, which interconnects all the computing resources in a metropolitan area. The new network has a data transmission speed 10,000 times faster than the previous technology, and it is expected to save tremendous amounts of money and paperwork for state agencies.

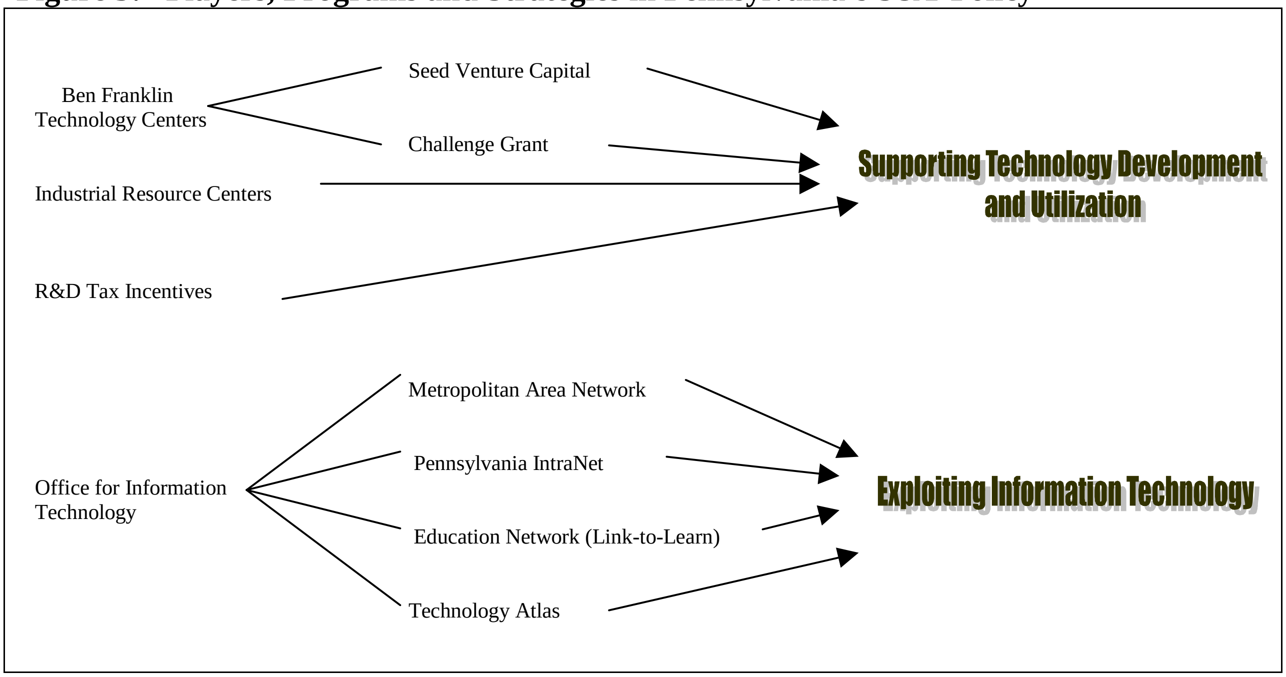
- The OIT has developed the Commonwealth of Pennsylvania **IntraNET**, which makes key business information readily accessible.

- **Link-to-Learn**, a 3-year, $132 million technology-based education initiative, is another good example of Pennsylvania's special attention to information technology and its utilization. The program improves educational technology, trains teachers, and interconnects classrooms to build the statewide and community-based Pennsylvania Education Network.

- The **Technology Atlas** for a New Pennsylvania was created by OIT as the nation's first digital atlas of technological resources. The project catalogued the spatial distribution of every technological resource at schools, colleges, libraries, museums, hospitals, government agencies, utilities and telecommunications companies in Pennsylvania.

Together these programs have launched Pennsylvania to a position of prominence in technological circles, primarily for the biosciences. Figure 3 summarizes Pennsylvania's approach to science and technology policy.

Figure 3: Players, Programs and Strategies in Pennsylvania's S&T Policy



Profile #3: Utah

Utah ranks 34th in population and 36th in GSP in the U.S. The composition of Utah's economy is a bit different from the nation as a whole: Its government sector is relatively larger (15.7% of GSP) than other states and is sixth highest in the nation. A significant portion of the state's economy (15.2%) is accounted for by manufacturing sectors even though this is slightly lower than the national average. For the last five years, Utah's economy has been one of the best performing economies in the nation in terms of GSP growth.

Players

The science and technology policy scheme of Utah is very decentralized, but two organizations are at the core of Utah's initiatives of technology development:

- The **Utah Technology Finance Corporation** (UTFC) is an independent nonprofit corporation founded by the state in 1983 to provide financial support for Utah businesses with high potential for product development and commercialization.

- The **Utah Office of Technology Development** (OTD), located in the Department of Community and the Economic Development, was created in 1986 and has coordinated Utah's technology development efforts through its Centers for Excellence Program.

It is also worthwhile to note two other organizations in IT policy. The **Utah State Office of Education** has played an important role in constructing a statewide electronic education network referred to as the Utah Education Network. **SmartUTAH** was introduced in 1994 as a nonprofit corporation to accelerate the proliferation of electronic commerce and electronic enterprise. SmartUTAH has played an active role in introducing the public to new ways of doing business and interacting using new technologies.

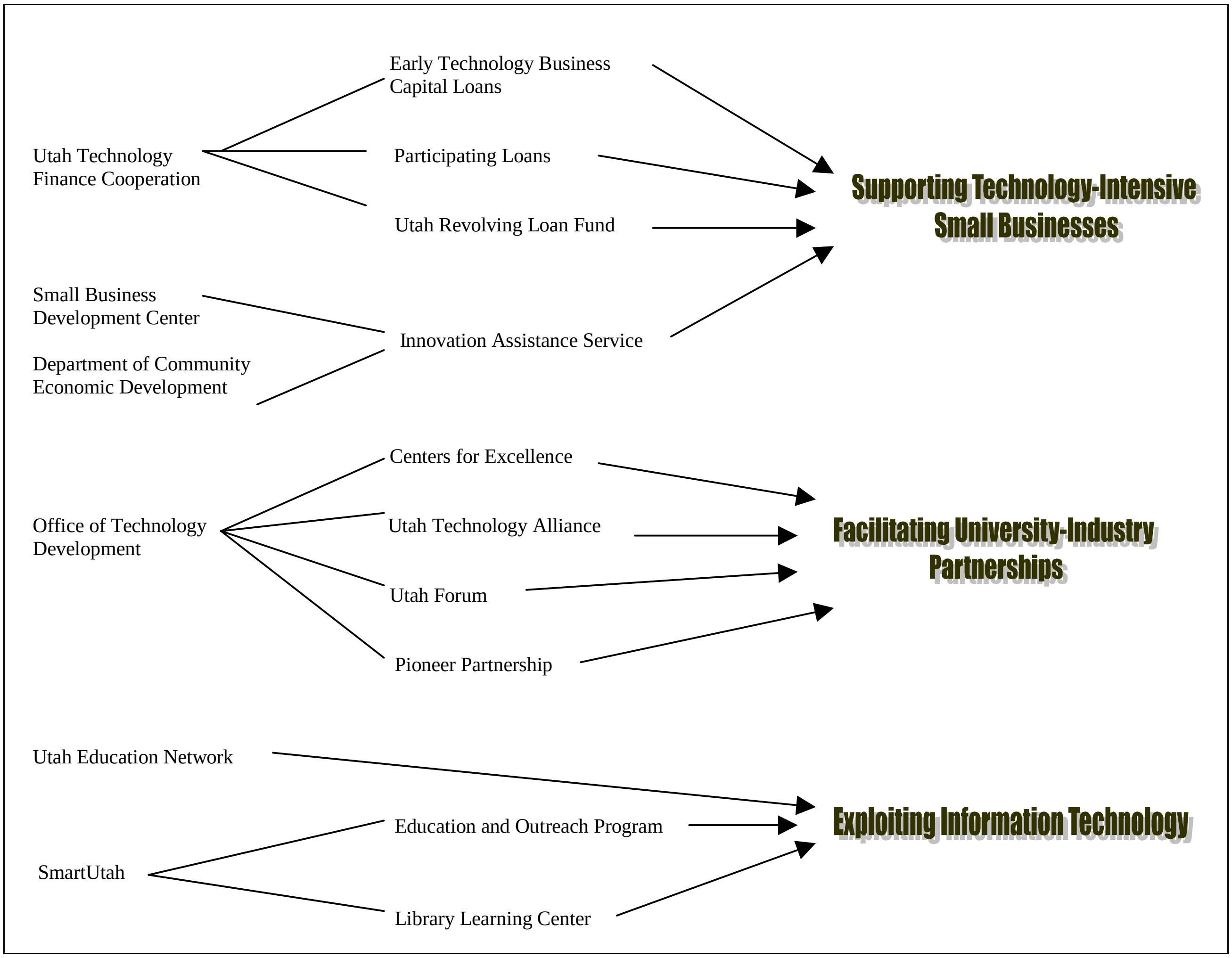
Strategies

Utah's reputation as a hotbed for leading edge technologies in biomedical and computer industry did not emerge until the mid-1980s, when the state started developing a new strategy to stimulate economic development via technology. Utah's major tactics in its science and technology policy are threefold: 1) supporting technology-intensive small businesses; 2) facilitating university-industry partnerships; and 3) exploiting information technology. Figure 4 summarizes Utah's initiatives in each of these areas.

Supporting Technology-Intensive Small Businesses

Loan Programs for Small High-Tech Businesses: UTFC manages a variety of loan programs to assist business creations and expansions. Through loans, UTFC aims to stimulate investment in high-tech companies in Utah by leveraging state funds with federal and private resources. By 1993, the loan program had created about 6,500 jobs. In 1993 alone, 58 loans were approved totaling $2.6 million and leveraging more than $6.6 million. The loan program is mainly focused on technology businesses. Major loan programs, such as Early Technology Business Capital Loans, Participating Loans, and Utah Revolving Loan Fund, are designed to provide financial support for existing manufacturing firms to upgrade their technology use and/or emerging technology-based companies. The UTFC's loan program is very similar to that of the Ben Franklin Partnership program of Pennsylvania, but the scale is smaller.

Figure 4: Players, Programs and Strategies in Utah's S&T Policy



Innovation Development: In 1992, the Utah Small Business Development Center and the Utah Department of Community and Economic Development jointly introduced the Innovation Assistance Service (IAS) which helps small firms to develop and to commercialize new products and services. IAS provides technical and commercial evaluation, market research, and workshops on specific issues related to new products and services. The funding is provided through OTD.

Facilitating University-Industry Partnerships

Support for Commercialization: The Utah Centers of Excellence Program, implemented by OTD, was created 1986 to encourage commercialization of cutting-edge technologies developed at universities and colleges in Utah. The program provides funds of about $2 million annually for selected research centers involved in early product development activities. Centers are selected through a competitive request-for-proposal process. The focus area of each center varies, so that every center has its unique perspective and strategy; however, the mission of each center is to demonstrate a positive economic impact on the state's economy.

The program has been very successful so far. Out of 50 centers that have been funded by the state, seven became distinguished centers with over $10 million in pending research contracts. Since the program was initiated, 65 new businesses have started as spin-offs of the centers, and more than 1,250 jobs have been created. OTD has operated other programs supporting technology-based startup companies and university-industry partnerships. At the core of this program lies the belief (often referred to as the 'pipeline' model) that the effects of R&D activities are channeled into economic growth via production processes (i.e., commercialization). The science and technology policy of Pennsylvania and Georgia stems from a similar perspective.

University and Industry Alliance: OTD has introduced several programs to promote the cooperation between universities and industries. First, the Utah Technology Alliance Program (UTAP) promotes alliances between universities and technology-oriented businesses by providing one-time grants to satisfy critical needs. For example, when a significant shortage of skilled workers in computerized numerical control was reported, UTAP funded an incentive program to attract students into the field. Second, Utah Forum, an on-line interactive database, has facilitated technology transfer and the commercialization of new technologies developed at universities. Third, since 1986, Pioneer Partnership has brought together executives from governments, businesses, and academics to discuss the state's science and technology policy development.

Exploiting Information Technology

Utilization of Information Technology for Education: Utah has been very active in developing information networks and in utilizing information technology. One of Utah's major accomplishments is the Utah Education Network (UEN). The UEN is a statewide partnership designed to coordinate various kinds of electronically delivered instructions and services, including distance learning. The network interconnects public schools, colleges, universities, local businesses, local TV networks, and electronic high schools within the state. The UEN also includes the Utah System of Higher Education and the Utah State Office of Education.

Internet-Ready Utahn: SmartUTAH is another example of Utah's proactive position on information technology. Introduced in 1994 by Governor Mike Leavitt, SmartUTAH has acted as a catalyst to accelerate and enable information technology and its utilization. Drawing on the strong belief that technologically smart and ready "Utahns" will make Utah business more competitive and prosperous, SmartUTAH has educated citizens through the SmartUTAH Education and Outreach Program. The program is designed to prepare Utahns to use the information superhighway more effectively. The Library Learning Center Project is a major vehicle to accomplish that goal. Library Learning Centers are well equipped to satisfy the demand for the Internet. The centers have information professionals to provide one-on-one assistance to inexperienced users. In addition, SmartUTAH has designed the Internet and Technology Fair to allow Utahns to get to know currently available IT in a very casual environment.

Preparation for the 21st Century: Utah's commitment on information technology is well-reflected in the state strategic plan for information technology, *Making IT Happen.* The plan includes a blueprint for further utilization of information technology resources, with these goals:

- prepare for year 2000 compliance
- move government on-line
- become an integrated enterprise
- manage and fund IT as a strategic investment
- share data and IT resources
- develop IT personnel
- eliminate organizational barriers through IT

Profile #4: Israel

Since its birth in 1948, as a country without any natural resources, Israel has placed a special emphasis on advanced education and scientific research. Two strategic fields were military infrastructure and agriculture. Technologies developed for military purposes are now being used for the development of commercial products. Agricultural innovations to produce better-yielding crops are now a basis for bioscience fields. Israel had the highest GDP growth rate (average 6%) among OECD economies for 1990-1995. Its per capita GDP, $16,800, placed the country 21st among more than 200 countries in the world. Israel's fast growing economy is mainly fueled by high-tech industry, which has been experiencing unprecedented growth since the early 1990s. The total sales of high-tech industry in 1997 ($7.2 billion) increased by 10.7 percent over 1996, and the exports of high-tech related goods and services in the same year ($5.6 billion) jumped by 14.2 percent over 1996. Israel's high-tech industry makes a sizable contribution to the national economy, which in 1996 had a GDP of $92.3 billion and exports of $31.3 billion.

Israel's strength in science and technology is also well reflected by its position in the international scientific community. It boasted the first and third place in the world, respectively, in the number of scientific publications per capita and the citations of scientific publications by Israeli scientists per capita. In addition, Israel's investment in R&D (2.1% of GDP) and number of engineers (135 for every 10,000 citizens) are among the highest in the world. Figure 5 summarizes some of these accomplishments.

Figure 5: Facts about Israel's Science and Technology Presence

Foreign investment in high-tech industries has almost **quadrupled** from 1995 to 1996, reaching $850 million.

About **21%** of all undergraduates and about **50%** of all doctoral candidates specialize in **science, engineering, and medicine fields**.

Israel boasts the **1st** and **3rd** places in the world, respectively, in **the number of scientific publications per capita** and **the citations of scientific publications by Israeli scientists per capita**.

Israel's **investment in R&D**, **2.1% of GDP**, and **the number of engineers**, **135 for Every 10,000 Citizens**, are among the highest in the world.

Source: Ministry of Foreign Affairs Web Page: www.israel.org/mfa

Players

The coordinators of Israel's national science and technology policy are the **Offices of Chief Scientist** (OCS) in major ministries. In 1968, the Israeli government established an OCS in the Ministries of Agriculture, Communications, Defense, Energy (today the Ministry of National Infrastructure), Health, and Industry and Trade to promote the development of high-tech industries. Today, thirteen major ministries have an office of chief scientist.[1] The chief scientist of each ministry serves as an advisor to the minister on administration of science and technology policy and as a coordinator between Israel and foreign countries to promote international cooperation. The chief scientist is also responsible for providing financial aid to promising R&D projects, for training new enterprises, and for nurturing technological incubators.

The **Ministry of Science and Technology** is another important player. Its major goals are to improve, consolidate, and expand technological research. The Ministry also provides advice to other ministries on science and technology matters and to help develop and and exploit the nation's potential in science and technology.

Strategies

As Figure 6 illustrates, Israel's science and technology policy has three major prongs: facilitating R&D activities, putting research into practice, and developing a well-prepared labor force for high-tech society.

Facilitating R&D Activities

Support for Academic R&D: Israeli universities play a major role in basic research and development, which is seen as critical to the country's technological advancement. About $260 million is spent on academic R&D annually in Israel, over half of which comes from the government. In addition, the government encourages researchers in universities to locate and apply for external research grants, most of which require international collaboration. About 2,000 research projects are funded each year by grants totaling $70 million. The Israeli government also has established a supercomputing center at Tel Aviv University to facilitate R&D activities in universities, research institutes, and industries.

Support for Industrial R&D: Israel's primary driving force for R&D activities is the Law for the Encouragement of Industrial Research and Development, which is administered by the OCS in the Ministry of Industry and Trade. The law was created in 1984 to promote the development of science-based industries. Based on this law, the OCS has heavily subsidized substantial industrial R&D and encouraged companies to invest in new product and technology development projects. One of major strengths of this program is its *ex ante* neutrality (Justman and Teubal, 1988).[2] In this way, Israeli government tries to minimize the distortion of intervening in the market. Under the law, selected projects are supported by direct grants for up to 66 percent of the project's expenditure. The grant is repaid through royalties on sales only if the project succeeds. In 1998 alone, the OCS distributed $500 million to about 800 high-tech companies including large corporations and small startups. Today, Israel boasts more than 1,800 R&D-based high-tech companies, which represent more than half of the country's manufacturing exports.

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[1] These are: Prime Minister's Office, Agriculture, Building, Communication, Defense, Education, Health, Immigrant Absorption, Industry and Trade, National Infrastructures, Public Security, Environment, and Science and Technology.

[2] Neutrality in support means that government supports a specific activity such as R&D without any explicit preference about branch, sector, or technology.

Some scholars, however, criticized the lack of tax-based support system (Teubal and Toren, 1986; Justman and Teubal, 1988). Although the grant scheme has been successful, many of Israel's high-tech companies have grown too large to maintain a reasonable level of grants for them. That is, their arguments focus on a well-balanced policy mixture between a grant scheme and a tax-based scheme. The tax-based scheme is believed to be more effective in supporting large firms, while the grant scheme is more appropriate for supporting small companies and start-ups.

Support for Regional R&D: The Ministry of Science supports five R&D centers in different regions of the country. The activities of regional R&D centers aim at increasing economic benefits and improving the quality of life through the contributions of scientists and engineers residing in those regions. The Ministry, in conjunction with each R&D center, supports various research projects designed particularly for the area involved. The major purposes of this research are to find solutions to common local problems, to strengthen Israel's research capabilities, and to foster social vitality to each region.

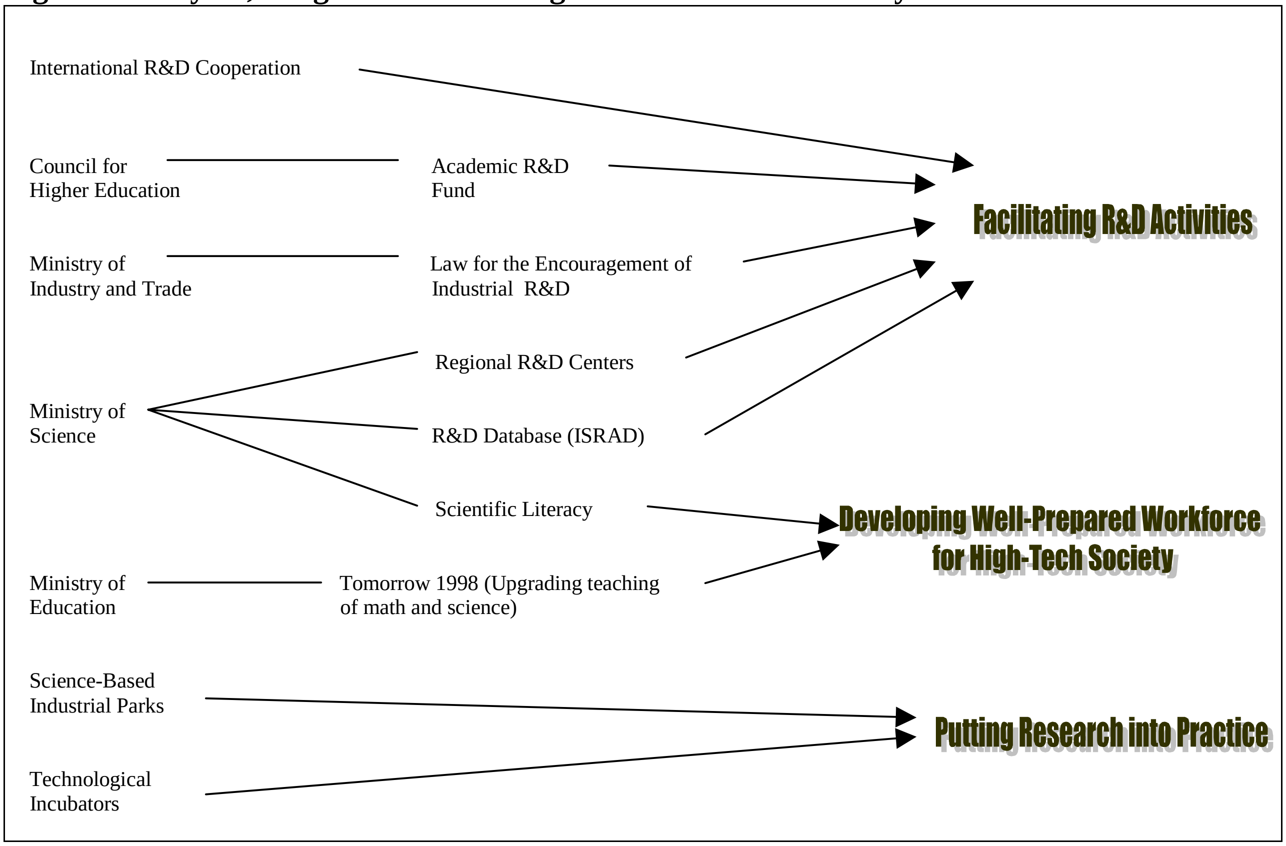
International Cooperation: Israel has established bilateral R&D cooperation agreements with 26 countries including the U.S., U.K., France, Germany, Japan, and South Korea. The agreements aim to develop continuous and steady working relations with major high-tech countries and to gain access to foreign funding sources by facilitating joint ventures in R&D. One of the most important recent developments is that **Israel has become an Associate Member of the European Union R&D Program**. The budget of the European program is approximately $16 billion for the five years, and 104 projects involving Israeli researchers have been approved.

R&D Database Development: As the Israeli academic science community is developing global partnerships in many interdisciplinary research projects, the need to share and to disseminate information is becoming more critical to collaborative projects. To meet that need, the Forum of University Research Authority Directors (FURAD) and the Ministry of Science are currently developing a national, comprehensive, and centralized database of academic R&D, referred to as Israel Research and Development (ISRAD). This database will serve as a primary information source for Israeli-based academic R&D and a linkage to industrial R&D databases.

Putting Research into Practice

Science-Based Industrial Parks: One of major tasks of the Chief Scientist is to encourage the commercialization of new technologies developed in university laboratories. The establishment of science-based industrial parks is Israel's main strategy to bridge academia and industry. Often located near research universities, the parks provide fledgling science-based industries with physical services and facilities as well as access to the intellectual capital of faculty researchers. This strategy has resulted in a close academic/industry relationship and great commercial successes. Many universities have set up spin-off firms in partnership with local companies to commercialize their research ventures. A very high proportion of university faculty advises industries on technical, financial, and managerial matters. The share of university research funding supported by the local industry is about 9 percent as compared with 6 percent in the U.S.

Figure 6: Players, Programs and Strategies in Israel's S&T Policy



Technological Incubators: Another important strategy to put research into practice is developing technological incubators. The first of this kind in Israel was introduced in 1991. Israel has 26 incubators throughout the country, which have graduated over 300 firms.

Developing a Well-Prepared Labor Force for High-Tech Society

Compared to other industrialized nations, Israel is poor in physical capital but rich in human capital. From the beginning of the country in 1948, high-skilled human resources have provided Israel with a comparative advantage in skill-intensive products. Two of its current programs for workforce development are described below.

Tomorrow 1998: Tomorrow 1998, initiated by the Ministry of Education in 1992, focuses on upgrading the teaching of mathematics, science and technology, which Israel recognized as critical to maintaining and enhancing national competitiveness in the future. The leaders of Israel believed that techniques dealing with modern tools should be introduced to children as early as possible, and that computers needed to be viewed along with reading, writing and arithmetic as a core element of education. A capital effort provided schools with computers to help create a technology-saturated environment. Today, virtually every student in kindergarten, primary and secondary schools uses computers and computer-related technologies.

Scientific Literacy: The Ministry of Science emphasizes the development of scientific literacy among children and adolescents through financial support for science museums and educational projects.

Profile #5: Singapore

The Singapore economy is relatively small in volume ($94 billion GDP in 1996), but it is a relatively rich economy with a per capita GNP of $24,700 in 1995, ranked 15th in the world. Based on purchasing power criteria, Singapore's per capita GNP surpassed that of the U.S. in 1998. The economy is well-diversified, with the largest shares being finance (29%) and manufacturing (22.7%), and it is highly open to international trade (trade/GDP ratio of 273%).

When the British left Singapore in 1963, it was a poor region with no natural resources or industries (Singapore was a part of Malaysia until 1965.). It was in 1965 that Singapore realized the need of transition and economic development. Singapore liberalized its economy and attracted many Multinational Companies (MNCs), including Texas Instruments, Motorola, Philips, and IBM, which brought the latest technology into Singapore. Singapore's per capita GNP growth rate for the last 35 years ranked first in the world. The remarkable annual growth average of 8.5 percent since 1960 has been achieved with a very low inflation rate of only 3 percent during the same period. Figure 7 summarizes some of the nation's more impressive achievements.

Figure 7: Facts about Singapore's Science and Technology Presence

About 10% of **science and technology graduates** pursue **R&D as a career**.

About 1.5% of GDP is dedicated to **R&D**.

In 1997 alone, a $100 Million **venture fund** was launched and more than 40 companies were supported.

Singapore boasts the realization of an **Information Superhighway**, Singapore One, which interconnects the whole nation and turns it into an **Intelligent Island**.

Sources: National Computer Board Web Page: regent.ncb.gov.sg and National Science and Technology Board Web Page: irdu.nus.sg/NSTB

Players

Unlike the U.S. system, the science and technology policy scheme in Singapore is very centralized. The **National Science and Technology Board** (NSTB) is at the center of science and technology policy in Singapore. Established by an Act of Parliament in 1990 as a statutory board under the Ministry of Trade and Industry, the NSTB has developed Singapore's excellence in selected science and technology fields and enhanced national industrial competitiveness.

The **National Computer Board** (NCB) is another very important organization initiating IT policy and development. NCB's mission is to exploit IT extensively to stimulate the economic growth and competitiveness and to improve the quality of life.

Strategies

Singapore has two major strategies in science and technology policy -- supporting R&D and exploiting IT -- and its two key government agencies, NSTB and NCB, are the leaders of these respective efforts.

Supporting R&D

To support the growth of R&D in Singapore, NSTB has provided funding for R&D, established R&D centers, developed the R&D workforce, and upgraded science and technology infrastructure. NSTB assessed the needs of science and technology in Singapore and developed a National Science and Technology Plan (NSTP) to provide national direction for science and technology development. The plan aims to increase the total expenditure on R&D up to 2 percent of GDP and the number of research scientists and engineers up to 90 per 10,000 labor force by the year 2005. The main thrusts of NSTB's science and technology development are described below.

Science and Technology Infrastructure: Singapore has developed some of the best telecommunications and transportation infrastructure in the world to enhance its competitiveness. The most prominent science and technology infrastructure in Singapore is a vibrant research area referred to as the **Technology Corridor**, where the National University of Singapore, the Nanyang Technological University, the Singapore Science Park, the Singapore Polytechnic Institute, and a growing number of research institutes are located. The Singapore Science Park is the cornerstone of the Technology Corridor. Launched in 1984, the park has attracted research facilities of hundreds of local and foreign companies, including Exxon, Sony, Seagate, Mentor Graphics, and Genelabs. The Science Park is still expanding; it is expected by 2001 to house an Innovation Center and a Technology Assistance Center to support startup companies. The park will also include a TeleTech Park, the first facility in Asia focusing on R&D in telecommunications.

Besides the physical infrastructure, NSTB also has focused on soft infrastructure. Technet, an electronic communications network linking researchers and industrialists in scientific community, was set up in 1992. The network interconnects all tertiary institutions and commercial R&D organizations. It links researchers in Singapore with international research networks and encourages international cooperation with their foreign counterparts.

Support for Industrial R&D: NSTB has made substantial progress in stimulating industry R&D activities. In 1997 alone, $1.14 billion was committed to R&D, which was expected to create approximately 1,400 jobs for research scientists and engineers. In the same year, gross expenditure on R&D increased by 17 percent, which accounts for 1.47 percent of GDP. The private sector led this growth by contributing 63% of gross expenditure on R&D, in large part responding to two programs that NSTB developed to support industry R&D activities:

- The **Research Incentive Scheme for Companies** (RISC) is a grant scheme to support companies that plan to develop R&D facilities in Singapore. In 1997, 28 RISC grants were awarded on a reimbursement basis. The selected companies receive grants covering up to 50 percent of their incremental R&D spending for 5 years.

- The **Research and Development Assistance Scheme** (RDAS) is a funding scheme to encourage industrial R&D activities and to raise the level of technological know-how in Singapore. RDAS is different from RISC in that it is designed to finance specific R&D projects by companies that already own R&D facilities in Singapore. The selected companies receive up to 50 percent of the total R&D project costs. The RDAS fund does not require repayment; however, as with Israel's R&D support program, projects that result in a commercialization must pay the NSTB a token royalty, approximately 0.5 percent to 3 percent of the product's sales revenue.

Innovation Development: The development of science and technology in Singapore was triggered by MNCs. In the 1960s and 1970s, MNCs arrived in Singapore with sophisticated technologies and skills, and many local enterprises upgraded their technology levels by adopting new knowledge from MNCs. Numerous ex-MNC employees have become entrepreneurs and commercialized their innovations. Two Singapore companies, Creative Technology and Aztec Systems, which hold a large share of the world's multi-media sound add-on card market, are good examples. NSTB created the Innovation Support Framework to help Singapore innovators come up with new ideas and inventions and to provide a supportive environment for new innovation. The framework has three distinct programs:

- The **innovators assistance scheme** (IAS) is designed to help innovators bring their innovations to market. In 1997 alone, a $100 million venture fund was launched, and more than 40 companies including 20 high-tech startup companies were supported.

- The **patent application fund** (PAF) aims to encourage organizations and individuals to register their new innovations and inventions and establish intellectual property rights.

- The **innovators club** is a social forum providing opportunities for innovators and researchers to exchange ideas, information, and experiences.

In addition, NSTB's Technopreneurs Assistance Center and Technology Fund provides seed funding and other supports for startup companies.

Workforce Development: The success of Singapore in science and technology development hinges on the workforce committed to it. The former Deputy Prime Minister of Singapore, Goh Keng Swee, explained that Singapore's success was based on its well-educated people. The turning point of Singapore's economic development was Texas Instruments and National Semiconductors' decision to choose Singapore as their base for semiconductor assembly. Mr. Goh pointed out that Singapore was able to compete against other locations for the assembly site because they had well-educated technicians and engineers, which other competitors such as Malaysia, Thailand, and Indonesia did not have. Singapore's electronics industry has burgeoned since the arrival of Texas Instruments due to the significant level of technology transfers to local companies, and is now the biggest industry in Singapore (Goh, 1996).[3] In 1994, the electronics industry accounted for about 43% of value added of all industries.[4]

Today, about 10 percent of science and technology graduates pursue R&D as a career, but NSTB wants to expand the size of this workforce further. RISC and RDAS provide funding for training scientists and engineers as a part of their programs. In addition, the Manpower Development Assistance

[3] By 1980s, the Economic Development Board matched local industries with MNCs such as Motorola, Philips, and IBM through a worker training program referred to as the Local Industry Upgrading Program to facilitate technology transfer.
[4] Source: *Yearbook of Statistics*, 1993, Singapore.

Scheme (MDAS) provides grants for postgraduate degrees and job training. NSTB, in conjunction with other agencies, also supports international R&D workforce recruitment under the Foreign Researchers Recruitment program to attract well-qualified and experienced foreign researchers.

Exploiting Information Technology

As the statutory board responsible for IT policy and development, NCB has designed and implemented many programs to enhance Singapore's economic competitiveness and quality of life by extensively exploiting IT. NCB developed five strategic goals for the next century: developing a global hub, improving the quality of life, boosting the economic engine, linking communities locally and globally, and enhancing the potential of individuals. Major programs to implement these goals are described below.

Vision of Intelligent Island: Singapore developed an IT masterplan for the 21st century referred to as IT2000. IT2000 plans to develop nationwide high-speed fiber optic information infrastructure interconnecting computers in every home, school, and office. It will provide a better environment for both business and daily life. The plan is also expected to turn Singapore into a global center for science and technology and a critical hub in global information networks and electronic commerce. A key milestone toward realizing IT2000 is to build an information superhighway network, **Singapore One**. Singapore One is an initiative to develop broadband infrastructure and a higher level of interactive multimedia applications for homes and offices. Its physical infrastructure, which will support voice, data, audio and video transfer, will far exceed the bandwidth of current Internet technology. Users will be connected to the network via highly sophisticated Asymmetric Digital Subscriber Line modems and Hybrid Fiber Coaxial connections. In addition to its high-capacity physical infrastructure, its applications will create an environment where interactive audio, video, and multidimensional graphics are common in everyday lives. Applications and services available through Singapore One include:

- On-line shopping, home banking, ticketing and other electronic commerce transactions
- News and information on demand including library services
- Multi-user on-line games
- Entertainment on demand such as video-on-demand and music-online
- Government services
- Videoconferencing and business to business services

Support for IT Development: NCB has established a $200 million Cluster Development Fund to facilitate the development of pioneering IT products and services, to re-educate IT professionals and users, and to develop information infrastructure. NCB has also developed various assistance schemes for local IT companies to upgrade and exploit their IT capabilities. Three examples of assistance schemes are as follows.

- The Innovation Development Scheme encourages local IT companies to develop capabilities for the innovation of new products and processes.

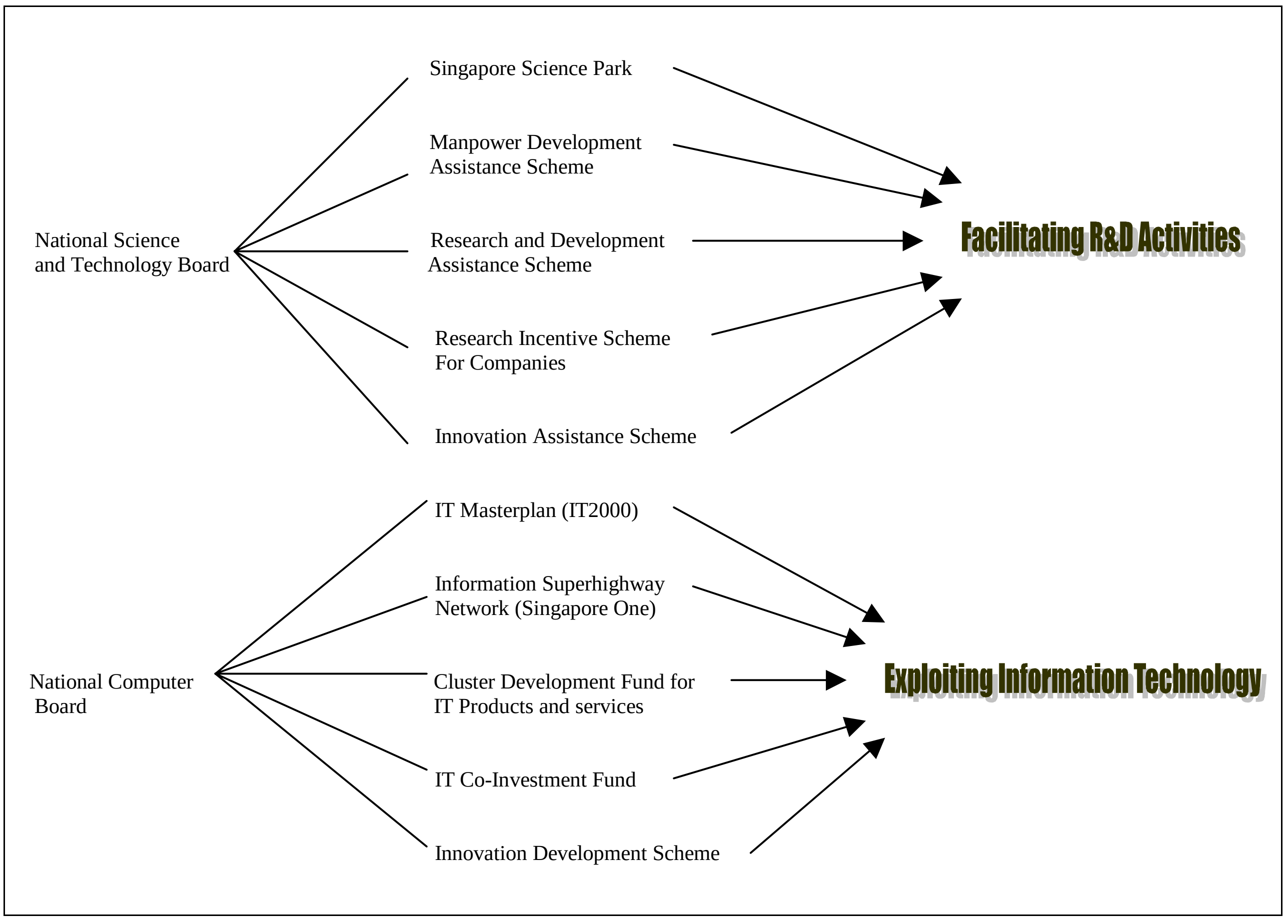
- The IT Co-Investment Fund supports investments in foreign companies to obtain new technologies.

- The Initiatives in New Technology program encourages workforce development in R&D, product design, and the application of new technologies.

Workforce Development: The NCB Scholarship Program provides financial support for promising young students in IT-related fields. The scholarship package includes all the costs for studying for up to six years at prestigious institutions in the U.S., U.K., Canada, France, Germany, and Japan. Today, hundreds of young IT professionals are studying cutting-edge technology at leading universities in each field.

These programs combine to make Singapore one of the undisputed world leaders in technology policy. Figure 8 summarizes the key aspects of this policy.

Figure 8: Players, Programs and Strategies in Singapore's S&T Policy



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