REPORT OF
VIRGINIA'S CENTER FOR INNOVATIVE TECHNOLOGY ON

THE STATUS OF THE COMMONWEALTH'S TECHNOLOGY ASSETS

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

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REPORT ON THE STATUS OF THE COMMONWEALTH'S TECHNOLOGY ASSETS
to the
JOINT COMMISSION ON TECHNOLOGY and SCIENCE
of the VIRGINIA GENERAL ASSEMBLY

(as requested by the Senate and House through Senate Joint Resolution 226)

Submitted by

Virginia's Center for Innovative Technology

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PREFACE

Senate Joint Resolution 226, passed during the 1997 Session of the Virginia General Assembly, requested Virginia's Center for Innovative Technology (CIT) to report on the status of certain scientific and technological assets (S&T) located in the Commonwealth. The Resolution states that various emerging S&T assets show promise for commercial potential and that Virginia, through CIT, should monitor, support and capitalize on these assets when appropriate. Specific entities identified in the Resolution for reporting include the following:

- Applied Research Center
- Biotechnology Research Park
- Biotech Informatics Center
- Free Electron Laser
- Langley Full-Scale Wind Tunnel
- Smart Roads Project
- Virginia Institute for Micro-electronics
- Virginia Modeling, Analysis, and Simulation Center
- Virtual Reality Center (CAVE)
- Wallops Island Space Flight Facility

Structure of this Report

Each of the assets named above were requested by CIT to provide the following information: description and mission of their organization or center; staffing and funding levels; planned or existing economic impact of the organization or center; existing and future needs. This information is provided within this report where available.

Information pertinent to the Commonwealth's overall scientific and technological assets is also contained herein. Much of the information was provided by studies conducted or sponsored by CIT over the past twelve to eighteen months. The report is set contextually at a national, more global level, and examines Virginia's technological and scientific assets against those deemed to be critical to the nation and to the global economy.

The science and technology assets described in this report comprise only an initial list. This is, therefore, the first in a series of reports describing and evaluating a wide variety of the Commonwealth's S&T assets, their current and ongoing resource needs, and their promise in enabling Virginia to become a national and global technology leader.

In its next report, scheduled for Spring of 1998, CIT will provide further information specific to emerging technology industries within the Commonwealth.

While the analysis is unfortunately not yet available, information will be provided within that report pertaining to the availability and abilities of Virginia's intellectual resources to support its emerging technologies. Together, these reports are a critical first step in not just examining the S&T assets in Virginia, but in evaluating the business and industry sectors where Virginia is most competitive vis-à-vis its intellectual resource capacity and capability.

This report provides the Joint Commission on Technology and Science with an understanding of where Virginia stands within a national context, as well as how the assets identified in Senate Joint Resolution 226 are faring. Finally, recommendations will be made to support these resources, as well as science and technology infrastructure within Virginia as a whole, by demonstrating their value to the Commonwealth's commercial sector.

Preparer contact information:

Dr. Eileen D. Heveron
Senior Director, Technology Industry Development
and Director of Intellectual Resources
Virginia's Center for Innovative Technology
2214 Rock Hill Road, Suite 600
Herndon, VA 20170
(703) 689-3043
(703) 689-3041 FAX
Email: eileen@cit.org

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EXECUTIVE SUMMARY

This report places key Virginia technology and science assets into a nationwide and international context. Among other findings, the report notes that:

- Virginia's science and technology assets as a whole, and those specifically mentioned in this legislative resolution, are key to supporting both existing and emerging technology-based industries in the state as they compete in the global economy.

- Existing science and technology assets must be nurtured over time, as they do take a significant period of time to develop prior to their having significant economic impact. They are, however, key to making Virginia a technology state.

- New opportunities to match Virginia's emerging technology assets with emerging industry sectors appear regularly. The State must be in a position to support the attraction and establishment of new resources.

Recommendations made as a result of this study are:

1. *Create a Technology Growth Fund*: The creation of a Technology Growth Fund, to be administered by CIT, will provide the funds needed to meet matching requirements to compete for federal projects which create new research centers or R&D projects such as National Science Foundation Engineering Research Centers. In addition, the Fund would provide funding to capitalize on commercialization opportunities where Virginia has existing technological or scientific assets that when leveraged with state funds, significant economic development activity will result, such as at the Applied Research Center or the Virginia Modeling, Analysis, and Simulation Center. Finally, a fund will assist in the development of a statewide strategy and accompanying resources to identify, track, and attract R&D facilities and organizations to Virginia.

2. *Establish new Technology Innovation Centers*: Throughout this report, a number of CIT's Technology Development Centers were mentioned by name. These centers have, over the years of their existence, leveraged $7 in additional funding from industry and the federal government for every $1 in CIT funding spent. In 1996, seventeen new companies were spun up out of only nine centers, and over $50 million in competitiveness and over 700 jobs were attributed to work performed at eleven centers. It has been five years since CIT had funding enabling it to establish new centers. The creation of new Technology Innovation Centers, whose goals include not only technology development, but also application, commercialization, and a rapid response to meet the needs of businesses using the centers, is recommended.

3. *Statewide Strategies for Virginia's Future:* The Commonwealth currently is not capitalizing on all potential research, development, and commercialization opportunities because it lacks comprehensive statewide strategies in the following three areas:

   - First, Virginia does not have a statewide strategy for the attraction and ongoing support of federal research and development assets. The last such Virginia effort was saving Wallops Island from potential closure and the creation of the Virginia Space Flight Authority to develop the Virginia Space Flight Facility. This asset, which is expected to provide one hundred million dollars in revenue annually from operations and associated business activities when fully operational – to say nothing of the jobs saved and created, was rescued from potential closure in the final moments of decision making. No plans have been made from a statewide perspective to save, nurture, and attract other federally derived assets, now valued at well over $750 million.

   - Second, Virginia like most states does not enjoy a statewide, fully integrated technology transfer network. When implemented, companies will be able to identify at the touch of a button the intellectual property available in the Commonwealth as well as who to contact to license it. Companies will be able to find funding sources and strategic partners to develop and commercialize these disclosures. Through such a statewide strategy the Commonwealth will truly be an entrepreneur-friendly technology state.

   - And finally, the Commonwealth enjoys many benefits derived from university-affiliated Research parks such as the Biotechnology Research Park reported on in this report, as well as the Corporate Research Center at Virginia Tech, and two research park facilities in the greater Charlottesville area. A new research park facility is being developed in Prince William County and the Applied Research Center, reported on above, is almost completed. The value of these parks to developing Virginia as a technology state has not been documented statewide, nor has the appropriate level of statewide support to assist in their ongoing health.

   It is recommended that the Commonwealth support through CIT the development of statewide strategies for protecting and attracting commercial and federal research and development assets, for developing an integrated statewide technology transfer network, and for developing a statewide strategy to assist our research parks.

OVERVIEW: Putting Virginia's Technology Assets In Context

In 1990, the United States Congress required that a biennial report be issued from the White House Office of Science and Technology Policy listing technical and scientific areas critical to the survival of the country in the years to come. The first "National Critical Technologies" report was issued in 1991 and listed ten such critical areas. In the third of these reports, issued in 1995, there were twenty-seven such critical technologies. As defined by the legislation, "the phrase 'critical technologies' implies that some technologies are so fundamental to national security or so highly enabling of economic growth (emphasis added) that the capability to produce these technologies must be retained or developed (emphasis added) in the United States." (National Critical Technologies Report, March 1995, Appendix A.)

An answer to one of the most commonly asked questions, 'how does this affect me?', comes from Technology in the National Interest (Executive Office of the President, 1996, page 8): "Technical progress is the single most important factor in generating sustained economic growth, estimated to account for as much as half of the Nation's long-term growth over the past 50 years." Nowhere is this more true than in Virginia. A recently released study supported by Virginia's Center for Innovative Technology (CIT) and conducted by Dr. Roy Pearson and Ms. Bernadette Kulas of the Bureau of Business Research at the College of William and Mary, notes that "...while high-tech industries accounted for only 13% of the 1991-1996 Virginia job growth, directly and indirectly they generated 40% of the total real (inflation-adjusted) gain in employee compensation, at least 29% of the real growth in total personal income, and 63% of the increase in real Virginia Gross State Product." (The 1991-1996 Performance of Virginia High-Tech Industries, page 1). Building a Commonwealth of Technology, A Blueprint for Technology-Based Economic Growth in Virginia, describes how "Virginia's technology sector is already growing at more than three times the rate of the Commonwealth's overall economy." "The average technology sector job in Virginia," notes the Blueprint's authors, "earned $45,288 in 1996, compared to $26,608, the average wage in the Virginia economy as a whole." It is expected that "by the year 2002, the average technology sector wage could grow to over $65,000 per year" (Blueprint, page 3).

To put the information contained in this report in context, it is important to recognize that most if not all of the Virginia resources described have a primary mission that is not economic development per se. For example, Federal agency resources must be mission-related; however, most federal laboratories have as a goal the roll-out of discoveries that are not held secret to the commercial sector. Thus, they engage in economic development through their technology transfer efforts. University resources have as their primary goals the mission of teaching, research, and service. As these organizations take on the additional goal of impacting their local, regional, and statewide areas through economic development activities, efforts are again seen in the area of technology transfer to industry.

One of the most practical implications of the technologies identified as being nationally critical, and the Commonwealth's ability to compete within this context, is that Federal research and development funding levels follow the paths outlined by the national critical technologies. Federal agency funding, National Science Foundation research centers funding, and similar infrastructure funding sources, all address technologies important to the nation, as defined through the Report. As well, science and technology policy makers' and observers' predictions often follow in line with the critical technologies. Battelle's "B-Tip Special Report S: The Most Strategic Technologies for the Year 2005" is only one such example. (Battelle's and the National Critical technologies are listed in Table 2.)

THE STATUS OF TECHNOLOGY RESOURCES IN THE COMMONWEALTH

In late 1996, CIT completed a study that categorized and listed the many technological, scientific, and research and development entities existing within the state's colleges and universities, federal labs, and private sector organizations (Andrew Reamer and Associates for Virginia's Center for Innovative Technology, "Inventory of Technology Research and Development Resources in Virginia"). The 1995 National Critical Technologies Report describes the variety of research and development areas as being the most important through the next decade, and additional review showed that reports such as that by Battelle, mentioned earlier, also follow this format. Following is a brief analysis of the Commonwealth's standing in each technology area in terms of general assets found within the state, as well as the specific assets requested in the Joint Resolution.

Energy Technologies

In the critical area of energy, technologies are classified into those dealing with energy efficiency; energy storage, conditioning, distribution and transmission (also included in the Battelle report); and improved generation of energy. Such technologies can contribute to the nation's and to the state's competitiveness through increased output per unit of energy input and through export opportunities. The National Critical Technologies Report asserts that "the United States is generally on par with the best in the world in critical technologies that fall into the energy category," and has increased its position relative to Japan and Europe in the energy efficiency technologies over the past several years.

Within the Commonwealth, energy-related research and development (including that found within transportation technologies and environmental technologies) is fairly well supported through the state's universities and colleges. The Commonwealth boasts internationally known centers of excellence such as the Virginia Power Electronics Center (VPEC) at Virginia Tech, as well as several smaller but no less-

focused research centers and groups. One of the Commonwealth's largest federal facilities is a U.S. Department of Energy Laboratory, the Thomas Jefferson National Accelerator Facility.

At the time of this writing, the Virginia Power Electronics Center, for the second time, has been asked to submit a final proposal to become a National Science Foundation Engineering Research Center (ERC). At the time of this writing, the VPEC has submitted its final proposal, in partnership with 5 universities nationwide, and is awaiting word as to whether it will be placed in the final small group of institutions which will be visited by a team from the NSF. This NSF program provides its awardees with annual funding of over $2 million for up to ten years. The program requires both state and industry matching support and such support is often one of the "tie-breakers" in making these highly competitive awards. While VPEC has been highly successful in obtaining a strong industry match for its proposal, with the Commonwealth's budget structure and cycle, there are no identified state matching funds to demonstrate its support.

Environmental Quality

Critical technologies in the environmental quality category encompass those technologies that perform monitoring and assessment activities; remediation and restoration activities; and pollution avoidance and control activities. The Battelle report includes "green" processes and manufacturing technologies in the environmental quality area.

Virginia's environmental technologies industry sector is composed of those businesses providing analytical services, water treatment, solid and hazardous waste management, remediation and industrial services, and environmental consulting and engineering ("Technology Plan for Virginia: Environmental Technology," May 1997, published by a steering committee of environmental technology industry leaders). There are about 2,600 companies in Virginia employing about 35,000 people. Each of the sub-areas within this sector as a whole fit well within the national critical technologies. The Virginia environmental industry ranks 16th in total revenue compared to the 50 states, with revenues of $4 billion in Virginia in 1996. Virginia environmental industry ranks 14th nationally in terms of export revenues. A very important focus of this industry sector is to obtain acceptance of these technologies, and to export them overseas, where the market is robust.

While other countries are beginning to make strong advances in these areas, the United States is currently the leader in this field. Virginia's growing environmental technologies industry sector is supported through many small but well focused research and development centers at the state's universities, several federal laboratory facilities within our borders, and excellent auxiliary intellectual resources in such related areas as architecture (environmentally safe building and building materials),

environmental law, and medicine. An observation concerning the scientific and technological assets supporting this sector is that, unlike other sectors, the expertise applicable to this industry is found across disciplines, as opposed to within one or two academic areas. For example, expertise in biological sciences, chemistry, physics, all forms of engineering, agriculture and wildlife, systems, computation, marine and atmospherics sciences, mining and minerals, etc. are all applicable to some form of environmental technologies. It is important to note that none of the emerging assets mentioned in Senate Joint Resolution 226 directly support this sector. A center of excellence in the environmental technologies disciplines, or other focussed research and development center, would no doubt enable this growing Virginia technology sector to take international leadership of this field.

Information and Communication

Identified in the National Critical Technologies Report as critical to the global economy are technologies in the information and communications area, including

- *components (included in the Battelle report)
- *communications (included in the Battelle report)
- computer systems
- *information management
- intelligent complex adaptive systems (included in the Battelle report)
- sensors (included in the Battelle report), and
- *software and toolkits.

(Those areas identified by an asterisk are identified within the Report to have the highest potential to contribute to economic growth, and those without to have the highest potential to contribute to national security.)

The U.S. is shown to have only a slight lead in most of these technologies. Technological advances in these fields are so rapid, the data in this area were no doubt out of date when the Report was prepared only two years ago. The Commonwealth is a leader in areas such as information management, telecommunications, and sensors. As well, it is the birthplace of the Internet, and hopes to become the home of Internet II and beyond. Within its borders, Virginia's college and university research centers are performing research and development in all of the areas listed as critical technologies, including those in related areas such as health informatics, robotics, virtual reality and the like. Although only a few have attained strong international reputations, many are poised to move forward in such rankings. But, while Virginia is the home of the Internet, no center of excellence across an array of emerging Internet technologies exists.

One resource supporting this technology area is Virginia Tech's Virtual Reality Competence Center, located in Blacksburg, VA. The Virtual Reality CAVE ™

(Computer Automated Virtual Environment) resides at this Center, which is a business partnership between Virginia Tech Intellectual Properties, Inc., and Prosolvia, Inc., an international pioneer in virtual reality software and simulation applications. The National Science Foundation-Academic Research Infrastructure (NSF-ARI) CAVE ™ was funded in September 1996, and in a subsequent proposal to NSF, VA Tech became a partner with the NCSA Partnership for an Advanced Computational Infrastructure (PACI). This leveraging of both resources and partnership is a model within the Commonwealth.

The mission of the CAVE is to enhance the economic and educational strengths of industry and academic partners through the effective use of interactive virtual environments in core business activities. A virtual environment is a system that "creates an artificial three-deminesional world where communication is interactive with immediate response..." Industrial and governmental activities of the Center are directed at how currently available technology can be used to improve business and technology applications in new areas. For example, in manufacturing, prototypes can be built as virtual worlds rather than building real mock-ups. This leads to significant cost savings, shorter lead times to market, and other competitive advantages. The R&D activities of the center are directed at how VR technology can be improved and made easier for new and existing companies to make use of it. A large portion of that activity currently involves training and education for Center partners and clients.

The capital requirement of $2 million for virtual reality equipment and support facilities is approximately 75% in hand, and the Center has developed a growth plan to ensure that its operations will be fully supported within three years. The biggest constraints to growth for the Center are a lack of trained staff to develop virtual reality projects, and developing an understanding among the business community as to the value of using virtual reality. Additional funding of between $250,000 and $500,000 would assist in stepping up growth of the center, solving the problems noted above and leading to an excellent international reputation.

In developing another valuable resource in the Commonwealth, the Federal government has partnered with Old Dominion University, the City of Suffolk, the Hampton Roads Partnership, and the State, to capitalize on and leverage work done at the United States Atlantic Command's Joint Training, Analysis, and Simulation Center in Portsmouth, VA. Through this partnership, the Virginia Modeling, Analysis and Simulation Center (VMASC) was created in 1996. VMASC will stimulate economic development in Virginia, specifically in greater Hampton Roads area, through the attraction or start-up of companies around the area of simulation. VMASC will conduct research that develops and promotes the application of simulation technologies, facilitate education of simulation professionals, and serve as a source of world class expertise in this important field.

A planning study conducted by Booz-Allen in early 1996 estimated that the potential economic development value of the VMASC exceeded $175 million, not only through the start up or location of simulation-related companies in the area, but also

through actual sale of marketable software packages designed for specific applications such as urban development, port movement, etc. However, the planning study made assumptions of two year operating funds of close to $4 million, half of which was expected from the Commonwealth. Actual state funds for two years are only $1 million. Additional funding to meet economic development potential for the state would be an additional $1 million.

Living Systems

"Living systems" as a critical technology area includes biotechnology; medical technology (included in the Battelle report); agriculture and food technology; and human systems (Included in the Battelle report). The United States faces strong competition from both Europe and Japan in all of these areas. The Commonwealth is becoming known in several areas important to living systems, including a rapidly growing geographic clustering of pharmaceutical and medical devices companies in the greater Richmond area, which perform a significant amount of in-house research and development. As well, the Commonwealth is home to three medical and related health professional schools (at Virginia Commonwealth University, the University of Virginia, and at Eastern Virginia Medical School) which contribute greatly to Virginia's growing strength in living systems.

The Biotechnology Research Park, created in 1992 in Richmond, is an incubator facility catering to start up entrepreneurial research-oriented biomedical and biotechnology companies. Provided within the Park are such amenities as administrative offices, laboratories, fiber optic telecommunications, library, conference rooms and networking activities. Within the next 10 to 15 years, all 34 acres of the Park will be fully developed, increasing its value as an economic development tool. Based on its initial operations of about 20 months, the economic impact expected of the center as a function of investment is potentially 60 new jobs with a $2.5 million investment, 120 new jobs with a $5 million investment, and 200 new jobs with a $10 million investment. One-half of the growth of the Park is expected to come from its close affiliation with Virginia Commonwealth University and the potential for start-up companies from researchers and scientists. Average state support of research parks in the Southeast U.S. is estimated by the Park to be approximately 30% of annual operations; currently the Biotech Research Park receives only 6% of its annual operating budget from the State.

Virginia Tech has an excellent agriculture school making inroads in "ag-tech," supported in large part due to the Commonwealth's history in tobacco and other farming. Its Fralin Biotechnology Research Center is internationally known. In the Charlottesville area, due to research emanating from the collaborative work by faculty and researchers at the University of Virginia's Health Sciences Center and School of Engineering and Applied Sciences, health informatics, telemedicine, and related fields are enjoying strong growth. A review of R&D technology intellectual resources,

combined with three medical schools and five university engineering programs, shows that Virginia has the potential of emerging as a leading player in the living systems area.

Bioinformatics is an emerging technology field that holds the promise of revolutionizing health care worldwide. The Institute for Biosciences, Bioinformatics, and Biotechnology (IB3) at George Mason University represents a model approach to integrating basic and applied research, within a modern university, with the surrounding business community. IB3 operates as a consortium of George Mason University, the Commonwealth of Virginia, Prince William County and the American Type Culture Collection. Research in bioinformatics emphasizes computational biology, and addresses sequence arrays, database organization and subsequent mining of the human genome, optical computation, pattern recognition and image analysis, and biologically inspired computational modelling. The first building of the IB3 facility at the Prince William Campus of George Mason University encompasses labs, classrooms, offices, library, bookstore and cafeteria. A second building is scheduled for completion in April, 1998. The work involved in bioinformatics does not come without a price tag, however. Current needs are focused on capital and equipment necessary to build out the facilities. The work accomplished in the Institute could not occur without state-of-the-art Silicon Graphics computing equipment. And while the University was able to capitalize on its initial outlay of close to $1 million for the equipment (Silicon Graphics has named IB3 a national training institute for its products, thus attracting "students" from all over the country to Prince William County), the products have a useful life of only three years before the equipment is no longer leading edge. Ongoing maintenance and continued upgrading are necessary for the Institute to produce results that will capitalize on this promising Virginia asset.

Manufacturing

The United States is thought to be on par with, or a leader, in these manufacturing technologies categories which support almost all United States' industries: discrete product manufacturing; continuous materials processing (included in the Battelle report); and micro-nanofabrication and machining (inc. in the Battelle report).

Virginia hosts a number of centers at its colleges and universities that assist in the manufacturing technologies arena and are ripe for investment. Its crown jewel, soon to be operational, is the federal government's Thomas Jefferson National Accelerator Facility (TJNAF), home to the Free Electron Laser, the future of micro/nanofabrication and machining. The newly established Virginia Institute for Microelectronics and the Virginia Microelectronics Consortium also support the manufacturing technologies area (microdevice and semiconductor manufacturing). NASA Langley Research Center's robotics strength also contributes to the Commonwealth's leadership in this area.

The flagship research facility at the Jefferson Center for Research and Technology, located on the grounds of TJNAF, is the Applied Research Center (ARC). The Jefferson Center and the ARC are home to a unique collaboration of several universities (the College of William and Mary, Christopher Newport University, Norfolk State University, and Old Dominion University) working with TJNAF scientists on the scientific exploration and development of new technologies relating to new materials and processes of significant importance to industry. The City of Newport News erected the $14 million seven story, 122000 sq. foot laboratory facility to serve as a nucleus of what will be a key center for research, development, and commercialization in the Commonwealth. To date, industry membership includes ten companies such as IBM, 3M, Xerox, and university membership includes those mentioned above as well as three others, including two from neighboring states.

The Free Electron Laser (FEL), a key component developed from research used to create the Continuous Electron Bearn Accelerator at TJNAF, will be the first laser of its kind to generate "tunable" infrared (and later, ultraviolet) light at high power. The FEL utilizes TJNAF scientists' superconducting radiofrequency knowledge and expertise to build and operate the free electron laser for basic and applied research in materials science. The research strengths of this asset fall into three categories: accelerator technologies such as medical imaging, detector technologies, cryogenics, and real-time process control software; supply side technologies such as optics and laser manufacturing; and demand side, such as polymers, micromachining, nondestructive evaluation, thin films, and electronics materials. Of high interest to industry in manufacturing products for all applications, the FEL will be used in a variety of industrial projects from micromachining to modification of a wide range of materials used in everyday life to improving adhesion of polymers and metals to nondestructive evaluation of products. Next-generation light sources, environmental monitoring and cleanup, and computer component manufacturing are still other areas ready for commercial application of the FEL technology. Firms such as Dupont, IBM, 3M, Lucent Technologies, Northrop Grumman and a host of others are collaborating on the $34 million FEL project.

Another unique resource within Virginia resides at the University of Virginia in the Virginia Institute for Micro Electronics (VIM). Officially established in 1996, VIM promotes and facilitates microelectronics research, educational activities, and technology transfer in electronic materials, semiconductor devices and fabrication, electronic design automation, and microelectronic systems. It was created partly in response to the growing microelectronics and chipmaking industry in the Commonwealth and partly to unify the strong, existing, interdisciplinary microelectronics activities within the University of Virginia (U VA). VIM has already developed new and unique relationships between the university and industry, and focuses on the design for semiconductor manufacturability, nanostructure engineering, high performance optical and electronic devices, microsystems and adaptive microinstruments, process design and control technology, embedded microelectronic systems, and risk and environment.

Working in collaboration with Virginia's Microelectronics Consortium, VIM and other research centers are in need of world class facilities to fulfill their potential. Development of the 9,000 square foot clean room facility, currently under discussion with IBM-Toshiba in Manassas, Virginia, would be an excellent first step in providing these much needed facilities. Commitment to developing a resource like this would provide a new venue for the semiconductor industry in Virginia, that of leading edge research and development, in addition to manufacturing. It would provide the telecommunications industry with new avenues in device development and manufacturing as well.

VIM is also a key entity within the University of Virginia's final proposal to the National Science Foundation to become an Engineering Research Center. As with the previously mentioned example of Virginia Tech's Virginia Power Electronics Center, U VA's Microelectronics Research Center was invited to submit a final proposal to the NSF and state matching funding has not been identified to support this important opportunity.

Materials

The United States' position in materials (included in the Battelle report) and structures, the two components of this critical technology area, is mixed. While the U.S. is well positioned in some areas, such as polymers and ceramic composites, it lags or is falling behind in others. The federal government has concentrated R&D funding for a number of years in materials and it is generally agreed that this policy is paying dividends. This emerging industry sector will be discussed in greater depth in CIT's report on emerging technologies in the Spring, 1998.

For the Commonwealth, the international reputation of Virginia Tech's faculty in advanced and intelligent materials, as well as the strong showing by several other Virginia colleges and universities in this area, speaks well of the state's ability to compete in this critical technology area. Materials research at Virginia Tech is found in all of the engineering sciences areas, and in specialized centers such as the CIT Technology Development Centers (TDCs), e.g., Center for Advanced Ceramic Materials and the Fiber and Electro-Optics Research Center, as well as several interdisciplinary centers in materials and composites, and research centers within physics, mechanical engineering, mechanics, etc. At the University of Virginia, the Department of Material Science and Engineering has three research centers supporting the materials industry sector. One of the strengths of the Free Electron Laser facility at Thomas Jefferson National Accelerator Facility is the commercial applicability of this resource for the materials industry.

Transportation

Transportation critical technologies areas are comprised of: Aerodynamics; Avionics and controls; propulsion and power (included in the Battelle report); systems integration; and human interfaces (included in the Battelle report). The United States has a strong lead in most of these areas, and the Commonwealth shines in several. The George Washington University Virginia Campus, for example, is home to the Transportation Research Institute's National Crash Analysis and Intelligent Systems Centers. Activities such as those involved in intelligent vehicles and intelligent highways, power electronics, human-machine interfaces, and systems management and integration, occurring at virtually all of the State's research universities, provide a strong support mechanism for the aerospace and transportation industries in the state. Examples include:

The Virginia Space Flight Center (VSFC) is an initiative of the Virginia Commercial Space Flight Authority, developed in partnership with Old Dominion University, CIT, NASA, and industry. Coresident with the NASA Wallops Flight Facility on Virginia's Eastern Shore, the VSFC engages in launch services, enhanced payload processing and integration, storage, radar, and telemetry services. The mission of the Center is to foster the development of a robust aerospace enterprise that serves to promote economic development, provides for education and research, and enhances the competitiveness of the U.S. in the aerospace sector. Through the Center, business finds a space launch infrastructure that is safe, capable, efficient and low cost known to few other states, access to state and federal technology, education, and research resources, and assistance in increasing competitiveness by retaining jobs that were to be lost and growing new ones.

The Virginia Department of Transportation , in cooperation with the Center for Transportation Research (CTR) at Virginia Tech, is creating The Smart Road. This represents the first highway in the United States to be built from the ground for intelligent transportation system (ITS) and it fills the void between a controlled laboratory environment and on-site real world deployment. The Smart Highway is a 6 mile, 4-lane limited access highway, built in stages. Besides ITS related exploration, the highway will be used for controlled testing and evaluation of vehicle dynamics human factors and "smart" engineering research. The Smart Road adds to the highway network of the greater Blacksburg area, serves as a testbed and test track for ITS research, testing , training and demonstration, and is a cornerstone in regional development of a transportation technology-based industry.

The Langley Full Scale Tunnel (LFST) is a large low-speed wind tunnel located within Langley Air Force Base in Hampton, VA. It is the second largest wind tunnel in the U.S. (and the largest currently operational, one of the four largest wind tunnels in the world, and the largest university-operated wind tunnel in the world (in 1996, Old Dominion University took over operations of the LFST). The LFST provides much-needed aerodynamic testing capability to the automotive and aerospace community

and supports research and educational programs. A longer term goal is to provide world class test capability for ground transportation vehicles. A truly unique facility, the LFST includes capabilities beyond testing such as engineering and testing support services, design, educational programs, and fabrication engineering services.

SCIENCE AND TECHNOLOGY INFRASTRUCTURE DEVELOPMENT IN VIRGINIA

While the Commonwealth possesses excellent assets in its research centers at colleges, universities, and federal facilities, the following less positive scenarios must be kept in mind when reviewing the value of technology infrastructure investments and their relation to economic growth and well being.

- The National Science Foundation, in its annual report on Support of R&D (Science and Engineering Indicators, 1993), noted that industry provided in 1991 over $1.2 billion for academic R&D. Of the top 200 schools, the top 25 received 33% of these funds, the bottom 25 only 3%. Virginia had no schools in the top twenty-five; with regard to total R&D expenditures at the top 200 schools, in 1994, only three Virginia institutions were listed, and those were ranked 45, 53, and 89. Note that these data are for all institutions, and that Virginia Tech ranks much higher than its 45th place when compared to institutions without medical schools. No matter how one looks at it, until Virginia's institutions can accomplish higher standings in this area, the Commonwealth will not develop the capacity or the reputation for broad-based cutting-edge research and development normally associated with top tier technology states.

- Science and Technology infrastructure development is a lengthy and expensive process requiring long-range planning and strategy, as the Commonwealth discovered through partnerships that led to the development of the Department of Energy's Thomas Jefferson National Accelerator Facility in Newport News. The Continuous Electron Beam Accelerator Facility (CEBAF) received $600 million in federal funding and took 16 years in building before its first research entity (known as a Hall) came on line. CIT's Technology Development Centers, planned to be fully supported and operational over a five year period, have taken on average over seven years to gear up and have required a much greater influx of funds than expected. Some have never, through a variety of factors, come into their own as expected. One cannot simply wish a laboratory, a research group, an applications oriented facility, to be operational when and if one needs it. The Commonwealth last made that long-term commitment with respect to TDCs some six years ago.

- The NSF asserts that there is ample evidence to suggest that a critical base of research is one of the fundamental requirements for location and growth of high-tech industries in a region (see various reports, including "National Research and Development Patterns," found at NSF's website:

http://www.nsf.gov/sbe/srs/pubdata.htm). NSF demonstrates that the current geographic distribution of R&D activities stem from innumerable past public and private sector choices made in light of multiple economic and scientific factors and considerations, not all of which are easily amenable to change. Absolute levels of R&D performance, they conclude, are indicators not only of a state's current capacity to support S&T based economic development, but also of a state's near term potential to build on its S&T base. "Half of the $145 billion spent on R&D in the United States in 1991 was expended in six states: California, New York, Michigan, New Jersey, Massachusetts, and Pennsylvania. Moreover, two-thirds of the national R&D effort was performed in ten states- the preceding six plus Illinois, Ohio, Maryland, and Texas. " The analysis shown in this report demonstrates that although Virginia has significant R&D activity at its colleges and universities, it has not nearly enough in any critical technology sector to build and sustain national or international reputation as a technology leader.

RECOMMENDATIONS: The Future of Our Scientific and Technological Resources

Virginia's intellectual resources must be supported consistently over the long term if they are expected to yield significant economic benefit to the Commonwealth. To give these assets the boost they need requires a state commitment well beyond current levels of support. Not only must Virginia support the needs of its current resources, a mechanism must be found to nurture new resources. The state must facilitate the discovery of new and improved technologies made within its intellectual assets and support their full commercialization, capturing the wealth and value of existing and emerging technologies and the latent capabilities of the Commonwealth. The recommendations that follow come not only from the evaluation conducted of specific assets listed in this report, but also from Virginia's industry leaders through the Blueprint for Technology Based Economic Growth in the Commonwealth. Virginia is on the brink of emerging as a top tier technology state. It has competitive advantage in a number of critical areas where, if the state committed to growing these assets, it could realize its potential to attract industry and federal funding, which combined with the state's commitment would lead to Virginia's emergence as a world class technology state.

Recommendations:

1. *Create a Technology Growth Fund*: The creation of a Technology Growth Fund, to be administered by CIT, will provide the funds needed to meet matching requirements to compete for federal projects which create new research centers or R&D projects such as National Science Foundation Engineering Research Centers. In addition, the Fund would provide funding to capitalize on commercialization opportunities where Virginia has existing technological or scientific assets that when

leveraged with state funds, significant economic development activity will result, such as at the Applied Research Center or the Virginia Modeling, Analysis, and Simulation Center. Finally, a fund will assist in the development of a statewide strategy and accompanying resources to identify, track, and attract R&D facilities and organizations to Virginia.

2. *Establish new Technology Innovation Centers*: Throughout this report, a number of CIT's Technology Development Centers were mentioned by name. These centers have, over the years of their existence, leveraged $7 in additional funding from industry and the federal government for every $1 in CIT funding spent. In 1996, seventeen new companies were spun up out of only nine centers, and over $50 million in competitiveness and over 700 jobs were attributed to work performed at eleven centers. It has been five years since CIT had funding enabling it to establish new centers. The creation of new Technology Innovation Centers, whose goals include not only technology development, but also application, commercialization, and a rapid response to meet the needs of businesses using the centers, is recommended. The funding commitment required to establish ten new centers to serve the Commonwealth's existing and emerging technology sectors, as recommended in the Blueprint for Technology-Based Economic Growth in Virginia, is $20 million over a fifteen year period (each center to receive up to $2 million, with funding levels staggered and peaking in years 2 and 3, over a five year period; two centers to be started annually beginning FY1999). This resource commitment does not take into account further long-term, consistent support for successful centers.

3. *Statewide Strategies for Virginia's Future:* The Commonwealth currently is not capitalizing on all potential research, development, and commercialization opportunities because it lacks comprehensive statewide strategies in the following three areas:

   - First, Virginia does not have a statewide strategy for the attraction and ongoing support of federal research and development assets. The last such Virginia effort was saving Wallops Island from potential closure and the creation of the Virginia Space Flight Authority to develop the Virginia Space Flight Facility. This asset, which is expected to provide one hundred million dollars in revenue annually from operations and associated business activities when fully operational – to say nothing of the jobs saved and created, was rescued from potential closure in the final moments of decision making. No plans have been made from a statewide perspective to save, nurture, and attract other federally derived assets.

   - Second, Virginia like most states does not enjoy a statewide, fully integrated technology transfer network. When implemented, companies will be able to identify at the touch of a button the intellectual property available in the Commonwealth as well as who to contact to license it. Companies will be able to find funding sources and strategic partners to develop and commercialize

these disclosures. Through such a statewide strategy the Commonwealth will truly be an entrepreneur-friendly technology state.

- And finally, the Commonwealth enjoys many benefits derived from university-affiliated Research Parks such as the Biotechnology Research Park reported on in this report, as well as the Corporate Research Center at Virginia Tech, and two research park facilities in the greater Charlottesville area. A new research park facility is being developed in Prince William County and the Applied Research Center, reported on above, is almost completed. The value of these parks to developing Virginia as a technology state has not been documented statewide, nor has the appropriate level of statewide support to assist in their ongoing health.

It is recommended that the Commonwealth support through CIT the development of statewide strategies for protecting and attracting commercial and federal research and development assets, for developing an integrated statewide technology transfer network, and for developing a statewide strategy to assist our research parks.

Table 1: SJR 226 S&T Assets

Entity	Mission	Funding Type	Strategic Need	Funding Needed
Biotechnology Research Park	Develop biotech/ biomedical industries	Combination of federal, state, city, and private	Financial – completion of facility	Capital ($15M) Operations ($.75M)*
Langley Full Scale Wind Tunnel	Provide test capability to transportation industry	Combination of state, private, with long term lease of federal asset	Financial – facility improvements Marketing	$100,000 to $5 million needed to complete facility
Virginia Modeling, Analysis and Simulation Center	R&D and application of simulation technol-ogies for industries	Combination of city, state, and federal	Financial – annual Marketing	$500,000*
Virginia Institute for Microelectronics	Facilitate micro-electronics research	Combination of federal, state, and private	Financial – annual Marketing	Not available at time of publication
Virtual Reality CAVE	Enhance strength of industry partners in use of interactive virtual environments	Combination of federal and private	Financial – start-up Marketing	$250,000-$500,000*
Applied Research Center	Provide R&D facilities to academic and industry scientists using FEL technology	Combination of city and state, followed by private	Financial - annual	Not available at time of publication
Free Electron Laser	Build a unique capa-bility for basic & applied materials rsch.	Combination of state, private, and federal	Financial – through partnerships	$1.5M* through university requests + $200K* for equipment
Smart Road project	Test bed/track for intelligent transport-ation R&D	Combination of federal, state, and private	Financial – research instrumentation	Not available at time of publication

Table 1: SJR 226 S&T Assets (con't)

Entity	Mission	Funding Type	Strategic Need	Funding Needed
Virginia Space Flight Center, Wallops Island	Provide space launch & services to govt. and commercial customers	Combination of federal and state	Financial – Start up – annual Facility completion	 $.6M* $.6M*
Bioinformatics Center (IB3)	Workforce training, education, basic/ applied research, distribution of innovative biotechnol.	Combined state, local, private	Financial - Annual Facilities completion	$300K* unavailable at time of publication

* = state support needed annually

Table 2
Critical Technologies Listing

National Critical Technologies (1995)

1. Energy
   - Energy efficiency
   - Energy storage, conditioning, distribution and transmission
   - Improved generation

2. Environmental Quality
   - Monitoring and assessment
   - Pollution control
   - Remediation and restoration

3. Information and Communication
   - Components
   - Communications
   - Computer systems
   - Information management
   - Intelligent complex adaptive systems
   - Sensors
   - Software and toolkits

4. Living Systems
   - Biotechnology
   - Medical technology
   - Agriculture and food technologies
   - Human systems

5. Manufacturing
   - Discrete product manufacturing
   - Continuous materials processing
   - Micro/Nanofabrication and machining

6. Materials
   - Materials
   - Structures

7. Transportation
    - Aerodynamics
    - Avionics and controls
    - Propulsion and power
    - Systems integration
    - Human Interface

Battelle's Most Strategic Technologies for the Year 2005

1. Genetic mapping and engineering
2. Innovative materials
3. Innovative agriculture and plant bio-technologies
4. Simple and intelligent human-machine interfaces
5. Higher density and mobile energy storage
6. Digital imaging and high definition TV
7. "Edutainment"
8. Miniaturized, highly personal electronic products
9. Cost-effective systems integration of sensors, controls, and power
10. Highly accurate and targeted medical treatments and drug delivery systems
11. "Green" processes and manufacturing technologies
12. Hybrid fuel systems for transportation

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SENATE JOINT RESOLUTION NO. 226

Expressing the sense of the General Assembly in connection with certain emerging scientific and technological assets located in the Commonwealth and requesting the Center for Innovative Technology to report on the status of such assets.

Agreed to by the Senate, January 24, 1997
Agreed to by the House of Delegates, February 20, 1997

WHEREAS, the Center for Innovative Technology (CIT) has demonstrated successful performance and leadership in serving technology-based companies and businesses in the Commonwealth; and

WHEREAS, over the last two years, CIT and its partners have helped to create or retain 5,571 technology-based jobs and have assisted in the start-up, attraction, retention, or conversion from a defense orientation to a commercial orientation of 130 companies; and

WHEREAS, companies and businesses assisted by CIT and its partners have achieved over $161 million in increased sales and increased capital funding; and

WHEREAS, evidence suggests that CIT is a performance-based, market-oriented organization which is regionally-based and industry-driven; and

WHEREAS, evidence also suggests that CIT demonstrates accountability and produces results of economic benefit to the Commonwealth; and

WHEREAS, although CIT has demonstrated success in providing "short-term" results, attention is needed in planning "long-term" and "mid-term" investments in the Commonwealth's science and technology resource infrastructure; and

WHEREAS, various emerging scientific and technological assets located in the Commonwealth show promise for commercial potential which Virginia should monitor, support, and capitalize on when appropriate; and

WHEREAS, included among those emerging assets are the Applied Research Center, Biotechnology Research Park, Biotech Infomatics Center, Free Electron Laser, Langley Full-Scale Wind Tunnel, Smart Roads Project, Virginia Institute for Micro-Electronics, Virginia Modeling and Simulation Center, Virtual Reality Center, and Wallops Island Space Flight Facility; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the Center for Innovative Technology be urged to monitor, support, and capitalize on such emerging scientific and technological assets located in the Commonwealth and to report on the status of such assets; and, be it

RESOLVED FURTHER, That the Clerk of the Senate transmit a copy of this resolution to the President of the Center for Innovative Technology that he may be apprised of the sense of the General Assembly in this matter; and, be it

RESOLVED FINALLY, That the Center for Innovative Technology be requested to provide the report to the joint subcommittee on science and technology created by House Joint Resolution No. 195 (1996) or a successor joint subcommittee or entity thereof on or before November 15, 1997 for inclusion in its report.