Programs for Emerging Technologies

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Forecasting Technical Program Needs

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Programs for Emerging Technologies

In general, Texas community and technical colleges have logical, well-structured processes for identifying program development needs to meet existing local needs. However, by their nature, these curriculum development initiatives tend to put primary emphasis on current needs. A process for identifying and analyzing emerging-technology program opportunities has been developed based largely on the needs and desires expressed by college deans throughout the state, plus direct input from a smaller representative group of community and technical college deans through coordination with the CCD and the formation of a CCD Forecasting Subcommittee. This process, entitled *Programs for Emerging Technologies (PET)*, is comprised of three essential components:

1) Identifying promising emerging-technology program areas.

2) Conducting meaningful technology forecasts for the identified technologies.

3) Disseminating resulting findings and technology forecasts to the State's community and technical colleges and other curriculum development stakeholders to promote informed and proactive decision making.

PET utilizes existing data sources and targeted surveys to reveal key indicators of promising emerging-technology programs applicable to Texas community and technical colleges. Once identified, outside vendors are utilized to conduct detailed technology forecasts based on the specific needs of instructional officers and other key stakeholders.

It is important to note that PET will undergo additional refinement in the 2003 project year as new data sources are identified and procedures further validated. This information will be collected in a centralized database and distributed online to all key stakeholders.

Identification of Promising Technology Program Areas

There is no crystal ball to predict which of the many emerging technologies available to forecast are likely to have the greatest workforce implications—much less warrant new curriculum development. Since it would be unrealistic and cost prohibitive to conduct forecasts for all of these technologies, a process is necessary to identify a select number of likely promising technologies for which forecasts should be conducted. PET incorporates a series of emerging-technology program indicators broken into three categories: defined, definable, and undefined. For each

of these categories, specific indicators, methodologies, and data sources are identified and explained.

Defined Indicators

The Workforce Education Course Manual (WECM) includes a database of all Texas community and technical college programs, courses, and associated data (i.e., contact hours, locations, etc.). When a college plans to develop a new program, they must first complete the "Application for Approval of New Workforce Education Programs" form located online at the THECB WECM website.[1] The majority of new program applications are not based on emerging technologies, but rather on already-existing programs. However, when an emerging-technology program application is created, this will be a defined indication of a new technology program need. Program revisions based on emerging technologies are also valuable defined indicators of new program needs. In both cases, this data is stored and readily available in the WECM database.

Definable Indicators

Anticipated new programs, scientific research, and economic development efforts throughout the state can indicate impending new technology program needs. Although these sources are less clearly defined than actual new programs, they are definable indicators. For example, if a significant number of instructional officers are planning to implement the same new emerging-technology program next year, there are numerous research activities and grants in the same area, and economic development corporations confirm increasing activity in the corresponding industry sector, there is a definable indication that this is a promising technology program area and additional in-depth forecasting would likely be beneficial.

In order to determine anticipated new programs, PET employs targeted surveys of curriculum development officers throughout the 69 Texas community and technical colleges. R&D funding can also be an early indicator of new emerging technologies, and the RAND Radius database helps provides insight into federally funded areas of scientific research and development. Targeted surveys of Texas engineering schools may also be employed to localize these R&D efforts and help identify key stakeholders in promising technology sectors. Texas economic development corporations and chambers of commerce will also be surveyed. These surveys are now under development and will be tested with focus groups before full implementation.

[1] See http://www.thecb.state.tx.us/ctc/ip/wecm2000/main.htm.

Undefined Indicators

Future trends, technology, and events can be difficult and sometimes impossible to predict, but they can also provide strong indications of impending workforce and curriculum needs. For example, trends in wireless networking indicate that continuous networking will be a reality in the coming years, recent technological advances in fuel cells and successful prototypes demonstrated by General Motors have made the long-awaited entry of consumer automobile PEM fuel cell stacks a foreseeable reality,[2] and increased security concerns resulting from September 11 have resulted in a flood of new grants and research in the defense and security sectors. These undefined indicators are unpredictable, and there is no single data source to rely upon, but these can be strong indications of an emerging technology trend and future impending workforce and curriculum needs. Beside typical news and information sources, futurist-oriented publications such as *The Futurist*, MIT's *Technology Review*, and several others can provide early insights into emerging technology trends. Additional reliable sources will be identified and categorized in subsequent program years. This component of PET is represented in the following exhibit and a graphic representation is included as Appendix K.

Exhibit 13

Identifying Promising New Technology Program Areas

	Indicators	Data Sources	Methodologies
Defined	New/Revised Programs: AAS, ATC, Certificates, LN, ST	Workforce Education Course Manual (WECM)	WECM SQL Database Existing Data
Definable	Anticipated New Programs	Instructional Officers Technical Deans	Survey Data
	Scientific Research	Schools of Engineering Research Funding Areas	Survey Data RAND Radius Database
	Economic Development Efforts	Blue Ribbon Task Forces Economic Dev Corporations Chambers of Commerce	Existing Data Survey Data
Undefined	Future Trends, Technology, & Events	Industry Leaders, Futurists Scientific Research Government Programs	Literature Reviews

Source: TSTC

[2] General Motors, *GM Hy-wire: Major Step Forward In Reinventing Automobile* (2002).

When the list of promising technology areas has been completed, a select number (six to eight) of specific technology areas will be identified for which technology forecasts will be conducted. This selection will be made by the PET team based on consideration of a number of weighted criteria. In general, criteria will be chosen and weighted in such a manner as to give special importance to areas of technology that offer particular promise of increasing, long-term growth and positive economic impact for the State of Texas. The list of criteria will include those identified in the recent survey, such as:

- The technology is likely to provide a meaningful number of well-paying jobs to two-year college graduates within two to four years.
- The expected workforce demands related to the technology are likely to increase steadily and significantly in the four- to eight-year time period.
- New curricula will be necessary to ensure that impending workforce demand will be satisfied.

Modifications to the Selection Process

Additional criteria will be identified by the PET team and other appropriate college, government, and business groups, and it is likely that sources and methodologies will be revised and updated as new or more effective data sources become available and are incorporated into PET.

Although the preceding paragraphs describe a structured process for technology selection, it is not envisioned that it will be applied mechanically. When appropriate, logic and independent judgment may replace formal methodologies. For example, an obvious emerging technology sector may be identified and selected for forecasting at any point in the program year, while, in other cases, it may become apparent that a previously identified promising technology is, in fact, unlikely to warrant new curriculum development, and research resources will be directed to other areas.

Results

In order to begin the forecasting activities earlier in the project, two technology areas will be selected that appear to be particularly attractive based on PET. TFs for these technologies will then be initiated immediately by an external forecasting vendor. The TSTC/TFI team has developed a detailed RFP and sample statement of work to guide vendors in the bidding process. This will ensure a broad range of forecast proposals and ensure the project does not depend entirely on a single vendor.

As described above, the identification process included in PET involves logical, structured, transparent mechanisms that can be moderated by logic. It is envisioned that this process will result in the selection of six to eight technologies that offer very promising opportunities for the success of the community and technical colleges of Texas and the economic wellbeing of the State. The next phase of PET involves the conduct of detailed technical forecasts based on these results.

Technology Forecasting Process

Purpose of Technology Forecasting

The fundamental purpose of formal technology forecasting is to project the nature, timing, and implications of advances in technology. The value of technology forecasting in assisting in the identification, design, and initiation of emerging-technology programs for Texas community and technical colleges will involve all three of these elements.

The importance of defining the nature of technology advances is obvious, for this will identify those areas of technology that have the highest probability of providing profitable opportunities for the businesses of the State.

The timing of the advances is also of major importance for colleges. If courses are presented too early in the technology development process, graduates will not be able to find suitable employment. If the courses are offered too late, the special advantages of early entry into a burgeoning field will be lost, and the workforce needed to support these technologies may not be available.

Finally, the implications of emerging technologies must be projected. In a society as complex and interactive as ours, new technologies have indirect and often unexpected impacts and consequences. The recognition and appreciation of these impacts and consequences will support better decision making with regard to effective curricula development and implementation.

Forecasting Tasks

Based on the identification process described in the previous section, six to eight formal TFs will be conducted as the second phase of PET. A forecasting agent with extensive experience in technology forecasting will be engaged to conduct formal TFs in each of the selected technologies. These TFs will be specifically designed to provide the colleges with insights and information that will be useful

in identifying and initiating new technology related programs. Each of these TFS will involve the following tasks:

- *Project the state of the art*. This task will involve projections of the manner and timing in which advances in technologies will occur. This effort will not only project how the basic characteristics of each technology will change over time, but will also identify possible spin-off technologies and novel uses of the technologies.

- *Project market potential*. This task will involve projections of potential market size for the new technologies, as well as analysis of how rapidly these markets will develop. Where appropriate, market segmentation and special conditions will also be examined.

- *Target Texas*. Of necessity, the first two steps must consider nationwide, and even worldwide, projections. However, for the purpose of PET, the implications of these technology and market developments for Texas are of primary interest to the people and industries of the State. Therefore, the broader projections must be targeted to the particular situations existing in Texas.

- *Validate analysis*. When the preceding tasks have been completed, it will be necessary to validate the results of the forecasting process. This validation must not only include an evaluation of the quality of the forecasts, but also the extent to which they are of value to the potential users involved. One of the most important elements in the use of technology forecasting is the confidence that potential users have in the validity of the forecasts. This task will be conducted in such a way as to support that confidence.*Identify opportunities*. To achieve the objectives of PET, the TFs must be translated into information and insights that will assist the Texas community and technical colleges in identifying, designing, and initiating emerging-technology programs that will promote the economic wellbeing of the State. A part of this effort will involve an examination of the relationship between the selected emerging technologies and the specific employment opportunities they will offer.**Planning the Technology Forecasts**

A successful TF must be based on a logical, carefully considered plan. Listed below are the basic steps that should be included in any TF project plan. Although these elements are arranged in roughly sequential order, in reality, several of the elements must be considered simultaneously or iteratively.

Objective—The objective of the TF project should be defined in clear, concise terms. The new information and insight that the TF is expected to provide should

be specifically identified. For this project, the objective has been defined as providing information and insights that will assist colleges in selecting, designing, and initiating emerging-technology programs that will enhance and expand the economic well-being of the State.

Schedule—Since the TF is being conducted to assist in decision making, final and interim results must be available in time to be useful. In PET, the TFs are to be completed during the second, third, and fourth quarters of the project year.

Scope—The TF plan must consider both the breadth of subject areas to be considered in the TF and the resources that will be made available to the project. In general, for a given level of effort, the more limited the scope of the forecast, the more detailed the forecast can be.

Approach—Early in the planning process, the approach or approaches to be used in the project must be determined. The approach to be used in this project is discussed later in this section.

Project Resources—Once the scope and approach of the project have been determined, specific assignment of resources should be conducted. As indicated earlier, the major portion of the forecasting effort will be the responsibility of the forecasting agent.

Project Organization—For the project to be conducted efficiently, organizational details must be specified. Details might include responsibilities of project personnel, reporting procedures, and administrative details. These details are either discussed in other parts of this report or are defined by various government directives.

Techniques—At this point, the particular techniques to be utilized in the study should be chosen. It is important to specify the contribution that each technique is expected to make to the overall forecast. One should also consider how the results from the different techniques will be correlated and/or combined. As the project continues, the mix of techniques can be modified as appropriate.

Evaluation Criteria—At the end of the project, its effectiveness and cost/benefit ratio should be evaluated. The PET team will be responsible for developing suitable criteria for evaluating the success of each individual forecast.

Forecasting Techniques

Depending on definitions, there are between 40 and 100 practical, proven techniques that can be employed in conducting TF projects. The most commonly used techniques can be usefully classified into five categories of forecasters: extrapolators, pattern analysts, goal analysts, counter punchers, and intuitors. Each

technique has its own strengths and advantages, but experience has shown that the most valid results are achieved when two or more of the techniques are used in concert. In Appendix L, the rationale supporting each of these five categories is presented, together with a listing of the methods and techniques associated with each category and an analysis of the key characteristics of each category.

The specific approaches, methods, and techniques that will be utilized to accomplish the previously listed tasks will depend on the specific situation involved in each forecast. Factors that will influence the selection of methods and techniques include the availability and quality of data, the desires and requirements of potential users, and the time and resources available for the conduct of the forecast.

Data Sources

A key element in the conduct and utilization of the TFs will be the collection and evaluation of data. College officials will not act on forecast results unless they are convinced that the forecasts are based on credible data treated in a logical manner. The terms "credible" and "logical" must reflect the beliefs of those who will use the results of the forecasts.

Successful accomplishment of the PET objectives will require an enormous amount of reliable, timely, and applicable data. Therefore, one of the key activities of this project will be the determination of the types of data that will be required and the identification of potential sources from which to gather this data. The data needed can be classified into three categories:

- *Previously collected and evaluated data*, such as types and size of State industries, current production figures, industry growth rates, and employment statistics. This data will be gathered primarily from existing records, databases, and appropriate publications.

- *Data involving projected developments*, such as planned growth of current State industries, expected new State industries, and related employment opportunities. This data will be gathered from published company reports, individual interviews, group meetings, and structured surveys of people who will be involved in decision making in the relevant industries and/or who are knowledgeable about developing trends.

- *Data involving a broad view of future technological possibilities*. This data will be used to identify disruptive technologies that might otherwise be overlooked. This data will be gathered from existing literature and interaction with future-oriented organizations and individuals. Periodicals that will be utilized include *The Futurist*, *Technology Forecasting & Social Change*, *Scientific American*, *Science News*, *Technology Review*,

Technology Research Management, and *Catalyst*. Books, such as *Engineering Tomorrow* by Janie Fouke, *The Virtual Corporation* by William Davidow and Michael Malone, *The Age of Unreason* by Charles Handy, *The Experience Economy* by Joseph Pine and James Gilmore, *Chemistry and Life Science: Visions of the Future* and *Physics and Electronics: Visions of the Future* both by Michael Thompson, and *Future Perfect* by Stanley Davis will also be used.

Personal discussions will be conducted with technology practitioners, such as university professors, technology news editors, and government officials, in appropriate agencies such as the National Science Foundation, the National Aeronautics and Space Administration, and the National Institutes of Health. In addition, prominent futurists will be consulted, such as recognized experts like Dr. Peter Bishop (Director, Futures Research Program, University of Houston at Clear Lake), David Snyder (President, Snyder Family Enterprises, a Washington, D.C., futures research organization, and co-author of the soon-to-be-published paper *The Strategic Context of Education in America: 2000–2020*), and Joseph Coates (former President of Coates and Jarrett, a Washington, D.C., futures research organization and co-author of *2025: Scenarios of U.S. and Global Society Reshaped by Science and Technology*).

Conduct of Technology Forecast Tasks

Project State of the Art

This task will involve definition of the current state of the technology, projection of how the technology will advance in the future, analysis of the implications of the advances in technology, and identification of possible technology spin-offs. The first step in this process will be to identify the key parameters for each technology, e.g., speed, weight, capacity, versatility, purity, and/or cost. When these key parameters have been identified, the current status of each parameter will be determined.

The next step in the process will be to project possible advances in the technologies. Various TF methods and techniques will be used to accomplish this end. One technique that might be used is *Technology Trend Extrapolation*. Experience has shown that, for most emerging technologies, key parameters follow an exponential improvement pattern. Thus, in using this technique, the forecasting agent will investigate past advances in the technology and search for identifiable patterns of progress. If such patterns can be identified, they can be extrapolated to project future advances. Observations that might indicate that technical change is imminent include:

- Changes in technical or economic performance.

- Changes in personnel and facilities.
- Funding announcements.
- Paper and meeting topics.
- Technical demonstrations.
- Program reports.
- Patent awards.
- New sales and advertising programs.

Another approach that might be applied to the projection effort is the use of *Precursor Trends*. Through the years, forecasters have found that developments in certain technologies follow a lead-lag relationship. For example, for several decades, new technologies developed for racecars have appeared in luxury production cars about four years later, in medium priced cars three years after that, and in inexpensive cars after another three years. To determine if this method can be useful, the forecasting agent will seek to identify any historic ties between the technology under consideration and some other related technology. If such a relationship can be identified, the forecasting agent may be able to project the state of the art in the lagging technology at some future point in time by observing the current state of the art in the related leading technology.

Another technique that might be used is *Analogy Analysis*. Experience has shown that patterns of progress are often repeated in different, but similar, technologies. For example, one could reasonably project advances in high-definition television, or even three-dimensional television, by examining the history of color and black-and-white television. In this project, the forecasting agent will seek to identify analogous technology development patterns and apply these patterns to emerging technologies.

Among the questions to be asked during this part of the TF project are the following:

- Where in the development process is the technology now, i.e. discovery/ concept, laboratory demonstration, field trials, or early commercial trials?
- What steps must still be completed?
- How long does it usually take to go from here to commercialization? Can and will they be compressed?
- Who is currently working on the technology?

- What problems are likely to occur?
- How fast can these be overcome?
- Are there parallel developments in progress?What are the required conditions for commercial success?As the forecasting agent is in the process of projecting future technical advance, a series of *Impact Wheel* and *Nominal Group* analyses can be conducted to add depth to the TF process. *Impact Wheel* analyses are structured to uncover unexpected and/or unintended consequences of new technology advances. In this technique, an advance in technology is postulated. The direct impacts of this advance are then identified. Next, the secondary impacts, i.e., impacts caused by the identified direct impacts, will be identified. This process is continued to identify tertiary and other higher-order impacts.

Nominal Group analysis is a specially structured method for utilizing the knowledge and insights of a group of experts through identification of key issues, discussion of these issues, and evaluation of the relative importance of these issues. In this part of the forecasting activity, nominal group analysis can be used to identify and evaluate exogenous factors that might impact advances in the targeted technologies. These analyses can also be valuable in identifying spin-off and follow-on technologies. Groups that might be involved in these analyses include:

- Members of TF Subcommittee of the CCD.
- Deans and other members of the community and technical college communities.
- Appropriate State agencies.
- Industry associations.

Project Market Potential

As the forecasting agent projects advances in technologies, it will also project how the market for the technologies will develop. The basic questions to be addressed are how large the market will be for that technology and how rapidly the market will develop. Related questions include:

- Will the technology be adopted by the market?
- How big is the potential market?
- When will the technology be commercially available?

- How fast will the technology penetrate the market?
- What are the factors of success?
- How long before the technology is obsolete?One of the most important steps in projecting market status is the division of the market into its various segments. Often, growth will be different for different market segments. Therefore, the questions indicated above will have to be applied individually to each segment.

Fisher-Pry and *Gompertz Substitution* models can often be used to project the rate of market capture. The former has proven quite accurate in projecting market capture in manufacturing and industrial areas, while the latter has proven more accurate for projecting capture in consumer product areas. Each technique utilizes an exponential curve to project how rapidly an emerging technology will be adopted in the marketplace. Experience has shown that:

- Both techniques can give a general indication of the rate of market adoption after only 1% market capture.
- 5% capture indicates that the emerging technology will eventually take over all of the market for which it is appropriate.
- Projections after 10% capture are reasonably accurate, although sometimes over-optimistic.
- Projections made after 20% capture are typically very accurate.

Input data for these substitution models will be gathered from the sources indicated above.

A number of secondary resources may also be used in projecting changes in the market status. For example, Infotechtrends.com gathers forecasts of market takeovers for a number of technologies. The Gartner Group and a number of other consulting organizations produce market forecasts in a number of technology areas. Moreover, in most industrial areas, there are commercial groups that gather market data on either a continuing or periodic basis.

Target Texas

By their nature, the projections described above involve national or even global trends. Because, however, the purpose of this project is to enhance and expand the economic wellbeing of the State of Texas, the overall projections must be tailored to reflect the situation in Texas. These projections will involve:

- Growth of industries currently located in Texas.
- The movement of key industries into the State.
- The development of new industries within the borders of the State.
- The establishment of mutual relationships between Texas industries and those of other states or countries.

It is envisioned that this step of the TF process will involve a series of interactions with knowledgeable people through *Structured and Unstructured Interviews*, *Nominal Group* analysis, and *Impact Wheel* analysis. Individuals, groups, and organizations that may be involved in this process include:

- Federal, state, and local government groups.
- Industry associations.
- Individual company executives and planners.
- University faculties.
- Advisory groups.
- College faculty and administrators.
- Labor unions.

Validate Analysis

The next task in the TF process will be to validate both the processes and the results of the forecasts. Potential shortcomings in these areas may include:

- The use of inaccurate or outdated input data.
- The use of improper forecasting procedures.
- Failure to properly evaluate exogenous factors.
- Failure to appreciate higher-order impacts and implications of technological advances and market development.

Constant vigilance will be necessary to reduce the probability of any of these shortcomings. Because of the number of data sources that will be utilized in the project, it is believed that the probability of using inappropriate data will be minimized. In like manner, the use of a number of different forecasting methods

and techniques should minimize the probability of improper forecasting procedures.

Two techniques will be used to identify and evaluate exogenous factors. The first will be a specially structured *Nominal Group* analysis in which a number of knowledgeable people who are familiar with the technology being forecast will be asked to identify trends, events, and decisions that might affect the individual forecasts. The group will then be asked to evaluate the importance of these factors in terms of importance, probability of occurrence, and time of occurrence.

The second method for analyzing exogenous factor will be the use of a *Stakeholder Analysis.* In this analysis, the individuals and organizations that will be impacted by the advances in technology or who may impact these advances will be identified. Next, the nature of their interest, their potential reactions, their ability to influence developments, and their commitment to their positions will be defined. Finally, all of these factors will be considered in concert to evaluate what the combined impact of these stakeholders might be.

Finally, to examine the impacts and implications of the projected advances in technology, additional *Impact Wheel* analyses will be conducted using the individuals and organizations indicated in previous parts of this section.

Identify Opportunities

The overall success of PET will be determined by the extent to which it assists the State's community and technical colleges in the identification, design, and initiation of emerging-technology programs that contribute to the economic wellbeing of the State and the long-term employment success of college graduates. Specifically, the types of information that can be expected from a carefully designed and conducted TF include the following:

- Clear definition of the nature of the technology considered.
- Projections of probable advances in each element of the technology.
- Projection of the rates at which these advances will occur.
- Definition of potential follow-on technologies.
- Projections of how large the market for the emerging technology will be and how that market will develop.
- Identification of the companies currently involved in the manufacture, distribution, operation, and maintenance of similar or related technologies.

- The implications of the advances in technology and development of market requirements to the State of Texas and associated groups.
- Identification of trends, events, or decisions that might serve as drivers or constraints on the projected advances in technology, development of markets, or implications of these advances and developments.

Once these elements of the TF have been completed, the results can be used to determine:

- Titles and definitions of potential jobs.
- Number of jobs that will be created by position, time, and location.
- Salary ranges for these jobs.
- The knowledge, skills, and abilities required for the various jobs.
- Required faculty credentials.
- Type and amount of equipment that will be required.
- Facilities that will be required.

Technology Forecasting Example

A TF on biometrics conducted by TFI in 1998 for the In-Q-Tel Corporation (then, In-Q-It) is attached as Appendix M. Although the forecast is somewhat dated and was not developed to support curriculum development, it can serve as an example of how a TF might be used to provide the types of insights and information listed above. The first part of the biometrics TF includes the following elements:

- A general explanation of the principles and purpose of authentication processes.
- A discussion of the tasks required in biometrics authentication.
- A detailed description of biometrics techniques that are based on physiological characteristics.
- A detailed description of biometrics techniques that are based on behavioral characteristics.

The value of this part of the TF to community and technical colleges is that it provides them with an understanding of the various techniques that might serve as

a basis for new technology-related programs. The next part of the TF provides a review of the current status of biometrics technologies, including:

- A review of the off-the-shelf systems currently available.
- A comparison of the strengths and weakness of the various systems.
- Projection of future market growth of the various systems.
- A listing of the companies currently offering products in each of the different biometrics systems.

This value of this part of the TF to community and technical colleges is that it provides them with a basis for evaluating the relative attractiveness of programs based on the various biometric systems. This information will also useful in determining which type of program would be most appropriate, e.g., an associate degree program, an advanced technical certificate program, or a local needs program. Moreover, the identification of companies offering products will provide a means for evaluating potential employment opportunities.

The final part of the TF projects more strategic industrial and technology trends. An appreciation of these trends will provide both community and technical colleges and State government agencies with a more strategic view of the future employment opportunities afforded by each biometric system.

Use of Technology Forecasting

An examination of the biometrics TF can illustrate how a TF of this type could be used to assist community and technical colleges in the identification, design, and initiation of new technology-related programs.

To begin with, a review of the "Dynamic Growth" section would have indicated that biometrics promised to be an area of rapid market growth, i.e., "one of the top ten emerging technologies for 1998." This would, in itself, indicate that the area was worth more detailed investigation. (The events of September 11, 2001, increased market attractiveness of authentication systems. Although the TF did not envision this particular undefined event, it did note the public's increasing interest in security systems.)

An examination of the types of biometrics approaches being investigated, together with the current state of the art of each, would have provided a basis for determining the times at which each technology would become attractive. For example, in 1998, fingerprinting was a well-established biometrics technique, although there was some interest in more advanced techniques, such as chip-based systems. At that time, iris recognition, although not widely used, was gaining

acceptance and interest as an authentication system. Other systems, such as keystroke dynamics, gesture analysis, and voiceprints, were being considered for authentication; however, their development and acceptance appeared to be well in the future. Based on these analyses, the community and technical colleges would have been able to determine which of these approaches best suited program development at their institutions.

An understanding of the different technologies involved could have served as a basis for identifying the types of jobs that would be involved in each technology and the skills, knowledge, and abilities required for each. This understanding could have also provided a basis for determining the geographic distribution of employment opportunities. For example, each of the defined biometrics systems will have similar types of jobs. These will involve research and development, manufacturing, installation, operation, and maintenance. The nature of these activities will vary between systems, but, in general, one would not expect research and development activities to provide many job opportunities for two-year college graduates, and manufacturing employment opportunists would typically be locally concentrated. However, the determination that installation, operation, and maintenance opportunities would be widespread could be of interest to colleges throughout the State. The skill levels, and consequently the pay levels, involved in each of these activities would differ.

Identifying companies offering products in each of the biometrics areas would have provided the colleges with a vehicle for examining specific job opportunities, skills, knowledge, and abilities requirements and probable salary ranges.

Next, an analysis of the factors listed "Industrial Trends" and "Technology Trends" would have provided the colleges with a more strategic view of the longer-term employment opportunities. For example:

- The emphasis on reducing the cost, size, and scanning and processing times defines the parameters that could be used to identify significant technical trends in each system.

- The increasing standardization in the biometrics industry indicated that a key step in the market development process was being achieved. This promised more rapid system acceptance.

- The movement toward integration promised more stability in the industry and, hence, more stability in employment opportunities.

- The recognition of the need for public acceptance of the various authentication techniques pointed out the necessity of consideration of non-technical factors in analyzing the attractiveness of the various authentication techniques. This factor indicated that the less obtrusive

systems would have greater market acceptance. (Public acceptance of authentication increased after the events of September 11, 2001.)

- The increasing number of multiple authentication techniques could have resulted in new desirable skills, knowledge, and abilities required for meaningful employment.

- The observation of rapid growth in the smart card industry highlighted an area that might be of particular interest to the colleges.

Finally, the list of "Interesting New Technology Developments" could have called attention to a group of technologies, such as holographic fingerprinting, facial thermographs, hand veins, and layered biometrics verification that merited consideration for the future, but did not promise employment opportunity in the timeframes of interest to community and technical colleges.

Beyond the potential value of valid TFs to the public two-year colleges listed above, experience has shown that the conduct and analysis of a well-planned and executed TF typically afford a number of ancillary values. For example:

- The TF often provides special insights into the less obvious aspects of the technology under consideration.

- The gathering of input data often results in the establishment of special relationships with people active in the industry.

- The identification of interest in a given technology often produces new data sources that might otherwise be restricted or overlooked.

Overall, the conduct of the technology identification and technology forecasting activities embodied in the Programs for Emerging Technologies (PET) process promises to provide powerful support to the community and technical colleges of the State in the identification, design, and initiation of highly promising new emerging-technology related programs.