The Missing Links between University and Industry In Taiwan

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1. Introduction

Technical innovation is the most effective way in enhancing the added-values of industrial products. A broad base of nationwide innovative industrial structure depends on effective participations of highly qualified technical human resources. However, in Taiwan, more than 70% of people with Doctor Degrees stay as faculty members in universities. It has been always the government's objective to promote university-industry collaborations and to encourage more professors and students engaging in R &D activities related to the developments of core technologies on campuses for local industry.

TSAY & CHU (2004) (Ref. 1) pointed out that the manufacturing-dominated industry in Taiwan has to develop toward the direction of high value-added industries so that high profit margins can be attained. Several measures have been proposed and implemented in ministerial levels for closer university-industry collaborations including personal motivations, motivating universities, and involving industrial participation in project evaluation and auditing. This paper is trying to find new approaches for possible long-term improvement of the relationship between universities and industry in Taiwan, which result in the overall potential for nation-wide innovations.

In Taiwan, the atmosphere for basic researches has been gradually improving and well recognized internationally. This is proved by the ever increasing numbers of published and scientifically-cited papers in international journals from researchers in Taiwan (Fig. 1). However, they are rarities that the results of academic researches have been applied to the industrial sector. On the other hand, the manufacture-oriented mindset in Taiwanese industry has limited them only in developing products aimed at lower cost or/and of higher quality, and paid less attention to the underneath core technology therein. The annual vast amount of technical imports (mostly, royalty payments) reaching three quarters of the governmental R&D budget in Taiwan (for example, in the year of 2008, technical imports amount to 75.7 BNT$, while the total governmental annual R&D budget was 99.3BNT$) (Ref. 2) reflect the situation clearly. Additionally, the academic society overlooks the importance of the scattered core technologies they developed in laboratories because of less inter-disciplinary team researches and thereby less effective integrations. It is widely known that, only after proper integrations, new innovative products can then be developed for the market. Thus, there are missing links existing between integrating the core technologies and product development, which hold up many possible innovations in Taiwan.

A lack of effective interdisciplinary joint efforts among faculty members and effective collaborations between academia and industry, which affects the overall innovative power, has drawn much attention to local society. Based on personal observation, the authors summarize the strength and weakness related to cultivating innovation in Taiwan (see Table 1). It is evident that many of the weaknesses reflect the lack of indigenous core technologies, which have to be developed and rooted locally, and their links to domestic industrial products developments.

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The authors believe that, starting a program to establish the core technology centers on campuses pertinent to specific academic fields and to meet domestic industrial needs is an effective way for a long-term solution. Industrial participation and more and more industrial contributions both of manpower and funding are the major measures of success as program proceeds. Guidelines for implementation are discussed in detail. In this regard, more than 25-year experience of US NSF (National Science Foundation) in sponsoring the Engineering Research Centers (ERCs) in universities across the country can be a role model for this undertaking in Taiwan. Although it is controversial about the cost-effectiveness of ERC program as appeared in some reports (for example in SRI reports), its effort in bringing inter-disciplinary researchers on campuses and even across universities together has been widely recognized. Above all others, students graduated from each ERC center were much more welcomed by the industry. They are becoming important innovators in related industry. Furthermore, international collaborations based on the existing Framework of Cooperation between NSF and NSC on this endeavor is possible, which are beneficial to both parties. Actually, several laboratories in Taiwanese universities were already invited to be collaborative partners of some ERCs in USA.

In the following sections, the definition together with descriptions about the proposed core technology centers envisaged is made, which serves as important guidelines in establishing the core technology centers on campuses. A separate section is devoted to absorb the essential features of the major ERCs of US NSF with vivid examples, which will provide as references for building up the core technology centers in Taiwan. Domestically, in order to find practical example in piloting this undertaking, the authors, after several personal visits to the site and discussions with the founder, choose one existing technology center, the Electric Motor Technology Research Center (EMTRC) in National Cheng Kung University as a leading case. Observed special features about this center together with its major achievements at different stages will be highlighted.

For the purpose to establish the centers of excellence in Taiwanese universities, the Ministry of Education (MOE) has started a 5-year 50Billions NT$ program for selected areas of research in different universities in 2011(see Table 2). Within some of the MOE-selected 34 centers at different universities, subprograms for specific core technologies can be worked out among the passionate professors. The authors believe this is a unique chance for Taiwan to establish the core technology centers on campuses with long-term vision of being sources of advanced technologies for future applications in local industry. Together with the related local industry and through careful strategic planning among the inter-disciplinary participants within the MOE-approved centers on campuses, some centers can work out in setting a long term (say, 10 years) goals with specified engineering systems as targets. All these can be put into proposals for review. Possible industrial participations in different stages will be expected, so that a sustainable university-industry ecosystem on R&D can be established. In so doing, with the acknowledgements of local industrial leaders and decisions in university level, the core technological centers can be started on campuses with active participations of faculty members even across universities. As we stressed, industrial acknowledgement even without contribution at the beginning phase is a pre-requisite and more and more contributions from the industry are expected in reaching a sustainable eco-system without continual government funding. At the same time and in a long run, the core technological centers are becoming special features to the universities they are belonging to.

In concluding remarks, based on the same governmental efforts with regards to building up the core technologies for industrial development, the authors make a general survey on government-sponsored R&D activities specifically addressing to potential industrial applications on campuses in selected countries on their budget-sizes and ways of implementation for comparison. Special attentions were also paid to the industrial participations and contributions to these endeavors. It is interesting to note that, similar to the 5-year 50Billions NT$ program of MOE in Taiwan, Korea has started the BK21 in 1999 for the sole purpose of university-level excellence. However, starting with its second phase in 2006, they added university-industry linkage as one of their priorities. Guidelines and suggestions in implementation are given for further discussions, so that feasible strategies and specific measures can be worked out for effective enhancement of the university-industry collaborations in Taiwan.

2. About the Proposed Core Technology Centers on Campuses

AMSDEN et. al. (Ref. 3) have applied a typology of R&D characteristics in analyzing the R&D activities in Singapore. They developed a set of generic questions. By answering each question appropriately, it reveals itself the belonging. According to the new typology as shown in Table 3, the R&D characteristics can be classified into five categories, which are; pure science, basic research, applied research, exploratory development, and advanced development. Based on this, core technologies that we are going to specify cover both applied research and exploratory development, while generalized research activities in universities extend from pure science to applied research. In contrast, industrial R&D covers both exploratory development and advanced development. With activities covering both university and industry, core technology centers fill the missing links between university and industry. Generally speaking, base on the needs from the industrial side, the major function of the core technology centers on campuses is to transform science and technology into knowledge industry with their in-house R&D achievements.

In order to differentiate in detail the core technologies carrying out on campuses from industrial R&D in private companies, the authors elaborate more in characterizing the core technologies from different aspects as shown in Table 4. This can serve as guidelines in the planning phase as well as in reviewing the achievements of the core technology centers. We describe it based on two aspects, namely, its nature and its functions, as in following paragraphs.

NATURE OF THE CORE TECHNOLOGY CENTERS ON CAMPUSES

Mainly supported by public funds, the core technology centers are interdisciplinary joint research centers led by faculty member(s). Basically, the research activities are knowledge-driven and search not only for know-how but also for know-why. Keep in mind the potential applications and the technology road map for product developments in domestic industry, the centers should have technical goals with milestones which are agreed upon by all participating faculty members but not jeopardize the academic freedom. With technological goals as major axis, research teams can choose their research topics. With the existence of core technology centers and participation of students, the spirit of open innovation is prevailing, which is essential to overall technology maturity. Above all others, due to interdisciplinary participations from different departments and even across universities and local industry, the center can easily reach a critical mass for engineering system development. The results will then be transferred to industry with calculated market profits and competitiveness. Generally speaking, the core technology center is established with long-term commitment of public funding (say, 10 years as ERC/NSF/USA the case). Gradually, it finds other funding sources based on its performance, so a sustainable ecosystem is formed and the links between university and industry, which were originally missing, have been established. On the other hand, judging alone from its educational nature for students, to build up the core technology centers on campus is a risk-free investment.

THE FUNCTIONS OF THE CORE TECHNOLOGY CENTERS ON CAMPUSES

As a platform for industrial participation—Industrial participation is a pre-requisite in establishing the core technology center. It thus provides as a platform for industry to meet professors and students on campus and also for joint activities. Most of the resources at the center are open for use by the industrial partners through membership arrangements or appropriate bilateral agreements. The center also provides opportunities for industrial leaders to get in touch with students either in doing research or in other joint activities. It is a perfect chance for the employers to observe the candidates before the recruiting. The center also acts as catalyst for technical collaborations among the private companies.
As a training center for industrial employees—The core technology center can work out intensive curriculum in training new entrants to industrial companies. This was proved as a more efficient measure comparing with trainings by companies themselves. Through these interactions, professors at the center will be invited as mentors to the company on specific technology.
As a test center for industrial products—Core technology center is equipped with facilities which are served to test and to qualify the industrial products developed by individual companies. Government can authorize the center to conduct specific tests. Based on the test results a certificate can be issued in accompanying the products to the market.
As a base for international and inter-university collaboration—Because of the conflict of interest, collaborations among companies in the same industrial sector is sometimes prohibitive. However, the core technology center can cooperate with other universities or even with foreign institutions. Actually, it was set as one of NSF/USA's guidelines to encourage its sponsored ERCs for international collaborations with aims to enhance US competitiveness globally. As a result, the industry can access to the state-of-art technologies through core technology center.
As a gateway for students entering related industry after graduation—It is prudent for university to provide students various opportunities in fitting individual aptitudes before their graduations for choice their career paths later on. Core technology center can serve this purpose.
As an open innovation center to industry—Contrary to private companies where the R&D activities are carried out exclusively for company itself, core technology center follows an open innovation path. Its research results can be openly shared by the potential users in industry. Special agreements are possible, so that participants with unique contribution to specific research can enjoy the right of first refusal in product development based on the results of the participated research.

Core technology centers accumulate the capabilities for domestic industries to develop next generation products. Mastering individual disciplines and interdisciplinary integrations are the keys to success. Specifically, prototype development and pilot plants, which provide as references for industrial manufacturing and scale-ups, become major projects of the core technology centers.

3. Highlights of the Engineering Research Centers sponsored by US NSF

Starting in 1985, the US National Science Foundation (NSF) has embarked upon the ERC program on university campuses across the country. Up to now, a total of 52 ERCs were established and each received and/or will receive at least 10-year consecutive supports from NSF. Among these, now 18 ERCs are on-going (see Table 5). Based on a survey in 2010 (Ref. 4), among the graduated 33 centers, 27 are self-sustaining with ERC-like characteristics, although without funding from NSF (see Fig. 2).
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The goal of NSF-ERC is to input knowledge and output an engineering system. Each ERC starts with a simple yet strict reviewing process. NSF's merit review process provides for a strict set of standards for these want-to-be ERCs. In addition, NSF requires that these institutions also provide money of their own so that NSF is only a supporter, and not the central investor. In this manner, NSF plays a supporting role in inspiring innovation. Most ERCs also have industry funding, which creates a unique bond between education-based studies and production assembly-line type thinking. This forms a long-term partnership where NSF acts as a government bond between educational institutes and the industry. NSF restricts the sectors in which it funds, thereby focusing development on needed industries. Furthermore, NSF conducts visits on the individual sites in order to ensure a suitable environment for innovation. NSF disqualifies any conflict of interest to ensure maximum probability of innovation.

EACH NSF-ERC BEARS A LONG-TERM VISION FOR NEEDED INDUSTRY

Before granting money to an ERC, NSF demands that these ERCs have a 10-year vision, which reflect in their proposal. This ensures that an ERC will not just solve a short-sighted problem, but continue to create solutions over this time period. NSF demands structured and strategic research plans to appropriately grant money. Although the initial grant of money on behalf of NSF may seem small, but the endorsement of NSF creates a confirmation for the industry to support the ERC. NSF essentially uses the process to gain credibility and ensure the industry that investing money will return good results. For example, the investments toward the CMU Data Storage Systems Center (1990-2001) contributed to the development of the NiAl under-layer utilized in hi-capacity small hard drives. These hard drives are now used in laptops and MP3 players.

Each ERC must have a 10 year vision, creating a plan for innovation, and thereby avoiding a possible misuse of funds. Each individual ERC has smaller clusters with smaller targets, and the combination of these individual goals creates an overall goal for the ERC. Each ERC has one general goal, and the individual components of that goal are carried out by different institutions to ensure the most efficient resource management possible. While the overall 10 year vision of an ERC is not always attained, the stepping stones toward that goal ensure that at least some innovation is completed within every ERC. This puts faith in the industry because even if an ERC "fails," it will still provide useful information for further information. For example, the Optoelectronics Computing Systems Center in University of Colorado/Colorado State University no longer exists, but provided the framework for further innovation. The existence of this ERC led to spinoff companies, eventually introducing 3D film technology to the industry. Therefore, even if an ERC does not actually meet its 10 year goal, the steps it takes toward that goal contribute toward further innovation in the industry.

EFFECTIVE REVIEWS GAUGING PERFORMANCE AND NECESSARY SUPPORTS

After granting the first sum of money to these institutions, NSF follows up with data-based performance with a composite baseline. Further funding is provided based on specific program needs, and assessed based on how broad and deep the program research is. NSF-ERC supports discovery, learning, research infrastructure, and science and engineering in education. The industry continues to play a critical role in the development process because NSF-ERC only contributes small sums of money, meaning that the industry must keep these engineering research centers alive. NSF continues to help in the development and evolution of these centers throughout this process. This 11 year process contains 2 renewals, ensuring that these ERCs are performing. Annual reviews also gauge the performance of each ERC to ensure that money is being granted appropriately. An ERC that produces more ideas may not be granted more money; rather, professional NSF reviewers gauge the amount of financial support a specific ERC needs. The data-based reviewing process removes much of the bias that could otherwise occur in a subjective review.

NSF CREATES STRONG CULTURE FOR INNOVATION TO INCREASE U.S. COMPETITIVENESS

NSF ERC has created the spirit and culture of a strong innovation based United States. It forms a bond between the industry and educational fields, provides a small sum of money, and helps turn intellectual property into industrial products. In 2006, NSF-ERC helped reform the production line. It transformed engineered systems, making a dramatic contribution to the industry. Although NSF-ERC only takes in $1 billion, its output as added value totals up to almost $50 billion (Ref. 5). The presence of the NSF and endorsement of an ERC serves as a reliable factor for the industry, thereby encouraging the industry to invest more money, creating a stronger industry and innovative power.

ERC was founded on the idea that innovation in multiple fields would help increase US competitiveness. While many product developments are based on the idea of profit, NSF looks to create new fields or deepen a certain field to push innovation forward. While the industry is profit-driven, NSF looks at creating a long-term solution for the US to stay competitive; therefore, NSF-ERC helps nurture new fields that may not seem relevant at present-time, but can prove to lead the US in terms of innovation.

PARTNERSHIP WITH INDUSTRY IS KEY TO SUSTAINABLE DEVELOPMENT

Partnerships with the industry have played a key role in the development of ERCs. These long-term partnerships ensure that ERCs continue to get funded, and so that the ideas generated by these ERCs are actually applicable in the industry. The industry then also has a nested interest in the performance of these ERCs. This creates sustainable ERCs for the future, even without further NSF support. Essentially, NSF only provides the first batch of funding in order to nurture this long-term partnership, and the industry and ERCs continue this relationship to spawn more innovation. Eventually, the centers that no longer receive funding from NSF are considered graduated ERCs, but many of them continue to be supported by the industry. As these ERCs continue to spawn innovation, the industry receives the advantage of this innovation, creating a long-term symbiotic relationship. For example, the Virginia Tech Center for power electronics Systems no longer receives funding from NSF, but continues to be supported by the industry. This ERC invented the multiphase voltage regulator in every Intel CPU based computer now.

ERCs MAKING OPEN INNOVATION A REALITY IN THE US

During the past 26 years, ERCs have continued to arise with new ideas for innovation. From data storage to nano-materials, all these ERCs have one thing in common: a culture of innovating, not just recreating. Each ERC opens up its ideas to the industry, but does not restrict who can access these ideas. Although some ERCs may own patents of their own, ERCs in general focus on innovating rather than holding intellectual property. For example, Columbia University’s Center for Telecommunications Research holds value patents for the MPEG-2 file, but shares their findings with the industry rather than keeping their findings as mere intellectual property. These discoveries are generally first shared with the industrial supporters of these ERCs, but do not have restrictive access. NSF ensures that the ideas it creates are ideas for innovation for the entire US. Therefore, the industry is free to access these ideas, making open innovation a reality in the US.

It was NSF's goal: using innovations generated from ERCs to keep the US ahead. Some ERCs focus on finding new discoveries that could arise to become new industrial fields, or perhaps a next step for the industry. With this spirit in mind, these ERCs continue to provide the industry with fuel for invention. For example, the Johns Hopkins University conducted a program to revolutionize surgical procedures with a combination of both human and machine technologies. However, these developments by the Johns Hopkins University were not withheld from the industry; rather, Johns Hopkins opened up this technology for the entire medical field to use: a definite move forward for the well-being of man-kind. These benevolent actions by ERCs spawn stronger industries in the US, making this a long-term sustainable relationship between universities and the industry.

MULTI-UNIVERSITY INTER-DISCIPLINARY COLLABORATIONS

Individual universities also collaborate to ensure a strong relationship. While each ERC contains a lead institution, several other institutions help conduct research. Tasks are delegated among institutions based on which institutions contain the equipment and facility to best conduct the research. This system of resource management creates efficient and effective ERCs. In addition, the members of different institutions can then collaborate and share differing opinions, preventing the results from having any possible bias due to completely depending on a single institution as a source. This also serves as a further attraction for the industry because the broad based research conducted by these institutions can only mean one thing: more dependable results. The industry does not partner with one single institution, they partner with a whole collaborative group: an ERC. This partnership ensures that even if a single institution no longer wishes to participate in the collaborative measures, or is no longer encouraged to do so, the entire ERC will not fall apart. Rather, the other institutions can keep the ERC alive and in collaboration with the industry.

ERC-STUDENTS WILL BECOME INNOVATORS IN INDUSTRY

NSF also supports diversity inside each ERC. Educational grants are given so that each ERC can continue to have supporting members. This forward-looking attitude ensures that ERCs are always contributing towards industries in the US. NSF increases the number of graduates who can contribute to an ERC or to the engineering industry in general. They target the students based on both merit and need to identify the students that will become innovators in the future. Either way, the long-term effect benefits the industry. This creates a strong link between research and education because NSF nurtures these students in the education field so that they can eventually return the favor with exceptional research.

Although NSF runs on a seemingly insignificant amount of money, its contributions greatly improve the development of industries in the US. NSF support provides a long-lasting bond between the industry and the university so that even after NSF stops granting funds to these ERCs, the symbiotic relationship will keep both sides running. NSF provides money where most needed, lights the spark, and allows the partnership to take off. This efficient use of money has shown how a culture of working together across institutions with the industry can prove to take a positive turn for all sides.

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4. The EMTRC in National Cheng Kung University in Taiwan- A Domestic Example

The Electrical Motor Technology Research Center (EMTRC) in National Cheng Kung University (EMTRC) has been in operation for more than 12 years. Joining with professors from Departments of Electrical Engineering, Mechanical Engineering, and Material Science, the Center has already established a close relationship and an excellent interaction with the industry. At the very beginning in 1999, EMTRC has set a long-term roadmap with a span of 10 years for its development. Now, after 12 years, most of the targets have been achieved. In the following, the authors specify more about EMTRC. It provides as a leading case for Taiwanese community to initiate the same endeavor.

EMTRC VIEWED BY THE LOCAL INDUSTRY

EMTRC is viewed as a technical center for electric motor and its control systems by the related industry partners. The center collects records, books, literatures, and research papers related to motor technology for the public. It is also acting as a database and information platform for the related industry. EMTRC also provides testing and measurement service to local companies with no charges. All these interactions have been tacitly enhancing the technical level of the motor industry in Taiwan. Overall speaking, EMTRC bridges the university and industry fundamentally through flow of talents. The students gets together (merging) in the center, receiving education and doing researches for 2 to 5 years, and the graduates are then well accepted by different companies (scattering). This merging-scattering model fits very well for small and medium enterprises, which dominate the Taiwanese industry. Thus, EMTRC provides a gateway for students in entering the industry after graduation. Some graduates are now serving as leaders in research and development in companies dedicated to motor research, such as Delta Electronics, CLEAN MOTION, etc. DELTA provides scholarships to students in EMTRC and, at the same time, the job opportunities after graduation. The graduates of EMTRC, mostly in industry (so far, only two became faculty members in Universities), have won wide recognitions among industrial employers

EMTRC is operated as an open innovation center to the local industry. It provides creative design ideas and design tools to local companies. However, it still depends on individual company to develop their unique products for the market. The local motor industry considers EMTRC as a "TEMPLE". It was Dr. M.C Tsai, founder of the center, who created this terminology, which shares very well within the local motor community in many aspects. Constant interactions exist between the center and industry partners. Joint activities have been frequently and voluntarily organized among them. For example, they have organized a delegation comprising leaders from individual companies to visit leading institutions of countries like England, USA, Germany, and Japan. In so doing, EMTRC automatically links the production chain in local industry with motor and its control system as major components or sub-systems. EMTRC also conducts on-the-job-training for employees in the local motor industry. Thus, EMTRC is considered as a preliminary training center for new entrants. The trainees know their teachers at EMTRC at the outset, who will be the mentors for their growth in technology. This teacher-student relationship becomes a basis of mutual trust between EMTRC and the industry.

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For the purpose of continuing learning for even broader community, EMTRC builds and maintains an on-line learning network on motor technology. Now, with a member of over 11,000, EMTRC's open system serves to broad area even including Mainland China. Through on-line Q&A and discussion, exchanges of technical knowledge are becoming convenient and prompt.

EMRTC acts also as an incubation center for spin-in of a company in developing certain technology. For example, EMTRC hosted for CLEAN MOTION for nine months in developing a high-efficiency

EC motor for primary-grade fans distributed in the market in Germany.

EMTRC VIEWED BY THE UNIVERSITY

From the university point of view, EMTRC is a good example for interdisciplinary research on campus and also for university-industry collaboration. It provides a good opportunity for students to engage into practical exploratory developments for industrial applications. Research topics have been constantly generated within EMRTC through its involvement in local industry. There have been 5 Ph D theses produced related to designs and prototyping of special motors for possible industrial uses. What EMTRC has achieved related to University-Industry Collaboration is also considered as role model to other universities. The newly established Electrical Motor Lab. led by Professor Cheng-Hu Chen of National I-Lan University, is an example. Prof. Chen was a graduate of EMTRC. It is widely recognized that graduates from EMTRC have been very much welcomed by the motor industry in Taiwan.

MULTI-LATERAL RELATIONSHIP

A multi-lateral relationship was established between the industry, EMTRC, and an independent third party (China Steel Corporation, CSC, the biggest fund provider), which secures the collaboration. This unique relationship enables EMTRC working as an open innovation center to all industry partners. EMTRC provides design tools to local motor companies based on steel produced by CSC, which secures indirectly the domestic market of CSC products.
Generally, EMTRC doesn’t collect membership fees from the S&M companies. However, companies like Delta Electronics, etc., still make voluntarily contributions and donations to EMTRC as recognitions. They also provide scholarships to students at the center and thus have the prior access to recruit them after graduation. For example, the Director and Program Manager for servo-motor development and manufacturing, which created hundreds millions US$ revenue for Delta Electronics was a graduate from EMTRC.

5. Guidelines for the Implementation of Core Tech Centers on Campuses

STATUS QUO OF RELATED PROGRAMS IN TAIWAN

In the framework of University-Industry collaboration, the Ministry of Education (MOE) has set both regional centers and technical centers on campuses in helping local industry in Taiwan (Ref. 6). However, most of these centers conduct predominantly training courses and services to industry. Overall speaking, MOE pays more attention to vocational skills and there hasn’t been long-term plan for building core technologies for potential industrial needs. Approaching from the industrial side, the Ministry of Economic Affairs (MOEA) is also aware of the importance of core technology. Thus, a program in welcoming international high tech companies to set up R&D centers in Taiwan (Ref. 7). In so doing, the related core tech will then gradually be rooted in Taiwan. Under this program, more than forty foreign companies started their branch unites in Taiwan. Yet each company has its own strategic plan in operating its units worldwide. It has shown difficulties in meeting the original expectations. Another program that MOEA started in 1996 was the establishment of incubation centers on campuses. Up to 2008, a total of 82 incubation centers were established. Several reviews were made on the accomplishments of this program and there have been signs that the programs are in declining in many campuses. Generally speaking, a lack of effective screening process to the proposal and insufficient funding sources for sustainable development were the major drawbacks. Additionally, local VCs have not shown their interest, which made the program in difficulty. The National Science Council (NSC) has been sponsoring R&D programs in supporting university-industry collaboration on a maximum of three-year basis. The importance of core technology has not been well recognized, which also affects the budget allocation.

AN UNIQUE OPPORTUNITY FOR IMPLEMENTATION

Under the MOE's 5-year 50 Billion NT$ program, 34 centers on 12 universities have been selected for awarding (see Table 2). Starting with these selected centers and within their available budget, and together with interested industrial representatives, professor(s) of involved disciplines and even across universities will discuss themselves for the formation of possible core tech center with characteristics as described in Sec. 2 of this paper. As a first stage, a group of faculty members for a specific core technology is formed. The newly established Taiwan Industry-Academia Consortium (TEMIAC) led by Prof. Ruey-Beei Wu of National Taiwan University can be considered as an example in this endeavor (see Ref. 8).

A 5-year proposal jointly prepared by the group of faculty members will be sent to the university hosting the core technology center. In preparing the proposal, the USNSF grant proposal guide can serve as a preliminary reference. In order to meet the actual needs of local industry, a road map for the specific technology together with the positioning of the prospective core technology center should be worked out as supporting document. The proposal should also take into consideration of the national needs. The pronounced six emerging industries (Ref. 9) and 2015 Foresight Industrial Tech for Taiwan (Table 6) can be as good references (Ref.10). It is commonly understood that the core tech center to be focused on sectors or technologies which capitalize on local and national strengths rather than have a wider spread of institutes in many technologies or industrial sectors.

After proper reviewing process, the project will be approved at the university level. In expecting the core tech center as a platform to industry and to manage the achievement of their objectives, certain high degree of autonomy should be granted to the center. Certain obstacles need to be overcome with possible innovative regulatory changes. For the operation, the 11year experience of the EMTRC of National Cheng Kung University as stated in Sec. 4 can be an example.

INVITING INDUSTRIAL PARTICIPATION AT THE ON-SET

The industrial participation from the onset is important. This can be worked out either through membership or bilateral agreements. It is also required to form a technical advisory committee as a guide and to overlook the major activities. A strong brand has been found to reinforce the core tech center by making it a more attractive partner to the industry and for international collaborations. Judging from its academia nature and its location on campuses, international collaborations are widely and easily undertaken without taking into account of any conflict of commercial interests.

IMPORTANCE OF THIRD PARTY REVIEWS

Besides the technical advisory committee as mentioned before, it is important to note that regular reviews on the performance of the center from an independent third party are necessary. For example, NSF/U.S.A. invited Stanford Research Institute (SRI) (Ref. 11) and Korean government invited RAND Co. (Ref. 12) making extensive reviews on ERC Program and BK21 respectively.

In order to invite a broad participation, the openness becomes an important culture of the center. A carefully designed website serves the purpose. Specific information can also be arranged to be accessible only to specific group of people. Publishing newsletters is proved to be an efficient and a timely way in having the advancements knowing to people in the related technology sector and the public as well. In this regard, achievement showcases are especially attractive. Besides, small size seminars and workshops are proved to be more effective in exchange of ideas than the large ones.

Overall speaking, each core tech center on campuses will build up and preserve its own features and tradition. A certain degree of freedom and autonomy should be given to the center during the build up phase and in operation as well. Many existing regulations, either set by the government or at the university level, should be modified in order to reach the effective and efficient status. In this regard, examples within Taiwan and from abroad as stated in this paper are valuable references in implementation.

6. Concluding Remarks

Besides the ERC/NSF in U.S.A. as described in detail in Sec.3, countries like Canada, England, Korea, have also government-sponsored programs on campuses specifically for technology development and with active participation from industry (see Table 7). NSERC of Canada started the sponsoring programs in 1978. In recent years, the total contribution (matching funds) from the industry has been always superseded the available government budget. This is an important index which reflects the successfulness. In England, the newly established Technology Strategy Board is responsible to creating technology and innovation centers (mostly on campuses) to transform the UK’s capability for innovation in specific technology areas and help drive future economic growth. In October 2010, Prime Minister David Cameron announced a 200 Million pound (including support the industry) for this purpose. It is worthwhile noting that England is trying to revitalizing its traditional strength in manufacturing for international competition. The recently established Advanced Manufacturing Research Centre (University of Sheffield), Nuclear Advanced Manufacturing Research Centre (Universities of Manchester and Sheffield), Advanced Forming Research Centre (University of Strathclyde), and National Composites Centre (University of Bristol) are evident examples (Ref. 13). In 1999, Korea has started a very aggressive program-the Brain Korea 21 program (BK21) for achieving the excellence of universities. A total investment of 3.5 Billion US$ spanning over 14 years has been allocated. Starting with the second phase in 2006, the university-industry links are among the priorities under this program. For the purpose of better coordination, a government-sponsored organization, the Korea core technology investment association was established (Ref.14). For Taiwan, to include with the core technology center program under the framework of the MOE-sponsored 5year 50Billion NT$ program starting in 2011 is the major advocacy of this paper.

There are many governmental-sponsored research institutions, although not located on campuses, also devoting R&D for industrial applications. Among them, the Fraunhofer-Gesellschaft in Germany is world-wide renowned (Ref. 15). Established in 1949 and now with its 80 institutes (60 in Germany and 20 elsewhere) and 18,000 employees, Fraunhofer is Europe’s largest application-oriented research organization. On average, the German government supports one third of its total budget (for example, in 2009, 550 Million euro of its annual total 1.65Billion euro was from the Germen government).

Belonging to this same category is Belgium's IMEC (Ref. 16). With staff of more than 1,900 people includes over 500 industrial residents and guest researchers and an annual budget of 285 Million euro (for year 2010 and including Belgium government support of 40 Million euro), IMEC performs world-leading research in nano-electronics and nano technology which applied in better healthcare, smart electronics, sustainable energy, and safer transport with success.

The core tech centers can serve the industry in a sustainable way yet not jeopardize their research nature on campuses. Unlike incubation centers on campuses, which many Taiwanese universities host for years, core tech centers have only a simple function for technology development, an accumulative and long-term effort to meet the needs in different industrial sectors. Actually, there have examples showing the strong technical competence in Taiwanese universities. Recently, INTEL Corporation sponsored a Connected Context Computing Center specializing in Machine-to-Machine technology in National Taiwan University for long-term research on Smart Sensing and Applications (SSA), Context Analysis and Management (CAM), Autonomous Reconfigurable Connectivity (ARC), and Green Sensing Platform (GSP). The US/NSF sponsored ERC on Smart Lighting at RPI also invited National Taiwan University and National Chao Tung University as collaboration partners. These all reveal that forming core technology centers are the right trend in setting foundation for technology competence.

However, not all government-funded core technology centers were successful. In 1985, Japan established a Key Technology Center (KTC) jointly under the jurisdiction of MITI and the Ministry of Posts and Telecommunications. Projects given major consideration in the first year involve clean diesel engines, fine ceramics, high function high polymer materials, bio-elements, aircraft, environmental improvement engineering, protein engineering, automatic translating telephones and optical memories. Based upon the original design and unlike most centers affiliating within universities as most countries did, KTC established a new research corporation if a project is undertaken. The center provides up to 70% of the company's paid up capital, up to a maximum of 10% of the total funds available to the center for such investments. The center sought to use patent fees to recover its investments in research-oriented companies, but fell short of the mark year by year. Until 2001, the government passed a bill to liquidate the money and called for the New Energy and Industrial Technology Development Organization (NEDO) and the Telecommunications Advancement Organization of Japan to take over the operations of the public corporation. Looking back, KTC was not under the jurisdiction of universities where student participations playing a key role and duplications with Japanese big companies where solid R&D bases already exist were the major reasons for the failure.

In addition to the research task force on universities, the existing national labs and other government-sponsored research institutes have made contributions both directly and indirectly to indigenous industry in Taiwan. The Industrial Technology Research Institute (ITRI) has been world-widely recognized for its significance in high tech arena in Taiwan. However, most of the ITRI successful stories were concentrated in product developments resulted in either spin-offs or tech transfer cases. Looking ahead, there will be more collaboration between these research institutions and the core tech centers on campuses. International co-operations are also encouraged. Furthermore, peer- and third-party reviews serve the purpose to guide the research directions and to bring the core tech centers to internationally competitive levels. It is to note that with the long-term accumulation of specialized core technology, it will gradually become internationally recognized features of the university the core tech center belongs to.

In conclusion, the authors would like to quote the original goals in starting the ERC program by NSF/U.S.A., which also can be applied to Taiwan in setting up the core tech centers on campuses. The goals are; (a) focused on a long-term vision important for industrial competitiveness, (b) integrated the traditional disciplines to address systems-level engineering research, and (c) formed university/industry partnerships in research and education. As it was in the ERC program, a companion goal is to use the core tech center concept as a catalyst to stimulate a broad-based change in the culture of academic engineering by integrating academic and industrial views, promoting the integration of research and education, involving undergraduates in research, and broadening the diversity of engineering graduates. The mechanism of the core tech centers was chosen as the means to accomplish those goals because the core tech centers can bring disciplines together. The core tech centers provide an integrated environment for academe and industry to focus on next-generation advances in complex engineered systems important for the Taiwan's future. Activity within the core tech centers lies at the interface between the discovery-driven culture of science and the innovation-driven culture of engineering, thus creating a synergy between science, engineering, and industrial practice. The core tech centers provide the intellectual foundation for industry to collaborate with faculty and students on resolving generic, long-range challenges to produce the knowledge base needed for steady advances in technology and their speedy transition to the marketplace.

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	Strength	Weakness
People	- High concentration of professionals - High working spirit and execution power - Entrepreneurs with global views - Experienced R&D management	- Manufacture-oriented mindset - Paying less attention to young entrants - Less patents led to commercial products - Less interdisciplinary collaborations
Environment	- Opening to & leveraging global resources - Fair respect to IP rights - Close and easy access to Chinese market - Flexibility with the small- and medium firms - Constant emerging of new business models - Increasing strength in product developments	- Foreign flagship companies hold most IPs - The domestic market is too small - Less divergence of strengthened indus. sectors - Less long-term R&D on core technologies - Less integrations on existing core technologies - Less university-industry collaborations

Table 1 Cultivating Innovation in Taiwan

Univesity	Name of the center	Description	Remark
National Taiwan University	Institute of advanced studies in humanities and social sciences	As platform for comprehensive interchanges between th humanities and social sciences	
	Center for information and electronics technologies(CIET)	Set up several common-use sub-field core research laboratories for supporting the next-generation key technologies in information, electronics, and communications.	
	NTU center of genomic medicine	Focus on disease-oriented genomic translation, with an emphasis on identifying mechanisms and generic bases for diseases common in Taiwan	
	Center of system biology	Conduct research on: creating quantitative model for complex biological systems and designing advanced algorithms for bioinformatics applications.	
	Center for advanced study in theoretic sciences	Targeting specific and most important frontier research topics, interdisciplinary teams are formed comprising mathematicians and theoretical physicists	
	Center for molecular biomedical imaging	Characterization and measurement of biological processes in living animals, model systems, and humans at the cellular and molecular levels using remote imaging detection methods	
	Center for emerging material and advanced devices	Peripheral labs include; nano-materials, nano-devices, micro-electric mechanical systems, and bio-nanomaterials & nano-educations	
National Cheng-Kung University	Research center for energy technology and strategy	Solar, wind, clean coal and algae bio-energy are major topics of research. Renewable energy combined with smart-grid system, clean energy and CO2-reducing/absorbing tech. Energy strategy and policy	
	Innovation center for advanced medical device technology center	Health-care robot, orthopedics device, nano- particle he therapy, implant materials	
	Infectious diseases and signaling research center	EV71 study, dengue fever study, gen and signal study	
	Advanced optoelectronics technology center	LED fabrication tech, heat dissipation tech, organic/flex optoelectronics & bio-science	
National Tsing-Hua University	Fundamental and applied sciences of matters	Combined research outputs in chemistry and physics	
	Interactive nano-x sciences	Nano-materials and characterization,nano-engineering and MEMS,nano-electronics and nanophotonics, nano/micro biomedicine	
	Low carbon energy	OLED, dye-sensitized solar cells, super capacitors, fuel cells	
	Connectomics	Reconstructing the brain’s wiring map,3D image searching, comparing, and browsing	
	Advanced manufacturing and service management	Integrating information communication tech, service management and design related disciplines to generate an open service innovation methodology, re-produce, re-use, re-design, and energy reservation(4R)	
National Chao Tung University	Emerging nano-electronics and system research center	Creating ultra-low power applications through device-scaling, novel design, materials, mechanism, integration, etc.	

	Intelligent information and communication research center	Targeting the intelligence and energy saving capabilitie future systems	
	Frontier Photonics research center	Nano-photonics, advanced laser, optical communication/information, image display and bio-photonics	
	Biomedical electronics for translational research center	To consolidate the immediate translational research need for bio-electronic devices for neuro-rehabilitation and cognitive function	
National Central University	Environment and energy		
	Complex Systems and plasma science		
	Optics and optoelectronics		
	Applied informatics: learning, enterprise, life		
National Yang-Ming University	Genome research center	Integration of genomic information, discovery of common demethylated zones in human cancer genome	
	Brain research center	Disease-oriented multidisciplinary and integrative researches	
National Sun Yat-Sen University	Asia-Pacific ocean research center	Discovery of new species in deep sea, marine culture, underwater archeology, habor management	
	Electronic commerce and technology innovation research center	Interdisciplinary research on economical and societal impacts of the Internet and innovative IT, such as ,electronic commerce, mobile commerce, electronic negotiation, and electronic decision making	
National Chung-Hsing Universit	The agriculture biotechnology laboratories	Genetic engineering studies	
National Taiwan University of S&T	The Taiwan building technology center	Research focus on; urban renewal, quality of life, environmental protection, and energy conservation	
Chang Gung University	The molecular medicine research center	Discovery of cancer biomarkers, translational research and personalized medicine	
National Chen Chi University	Chinese Mainland Research Center		
	Election Research Center		
National Taiwan Normal University			

Table 2 Under the MOE 5-year 50BNT$ Program
The Awarded Centers of Excellence on Campuses in Taiwa

	. Pure Science	Basic Research	Applied Research	Exploratory Development	Advanced Development
Search	Intrinsic Knowledge	Radically New Marketable Product	Product on paper	Prototype Product	Prototype Product for manufacturing
Research Objective	Uncover new scientific principle	New Science with applications	Transform Concept for new application	Implement concept as engineered system	Reduce costs, uncertainties of manufacturing
Output	Concept-based IP	Product-based IP Transfer to next stage	Differentiated product for specific market	Detailed product design prototype	Manufacturable product
Size of Effort	Depends on branch of study	Critical skill mass; specialization	Smaller group for exploiting niche from basic research	Depends on size of system	Related to production
Institutions	University Research (Generally)			Industrial Development	
	Pure Academic		Core Technology Centers in Universities		

Table 3 The New Typology of R&D Characteristics

Source: AMSDEN, A.H, TSCHANG,F. Research Policy 32,553-572 (2003)

	In Core Technology Centers on Campuses	In Private Companies
Natures	- Not only for know-how, but also for know-why - Mainly open innovations - Knowledge-driven, not for profit - With continuity and long-term goals	- Mainly know-how - Innovative products belong to the company - Profit-driven - Target-change follows the business needs
Pay Attention to	- New ideas - Publications - Interdisciplinary joint research	- New marketable products - Patentability - Potential added value of the product
Funding Sources	- Mainly public funds and also accept private supports - Long-term commitments	- Funded by company itself - May change with the business conditions
Independency	- High self-governance in selecting topics - Easier match with world leading researches	- Influenced by the major firms in each industry - With constraints, possible patent infringements
Collaborations with Outside	- Collaborations with outside are easy - Collaborations without cash flow between parties	- Restricted by conflicts of commercial interests - Collaborations based on take-and-give nature
Student Participations	- Student participation in research is required - Provide as platform for students to the industry	- Only regular employees participate - Contact students through Core Tech Centers

Table 4. COMPARISON OF THE R&D ACTIVITIES IN PROPOSED CORE TECHNOLOGY CENTERS ON CAMPUSES AND R&D IN PRIVATE COMPANIES

Research Area	Research Topic	Start Date	Host University	Participating University	Awarded $ to date
Biotechnology And Healthcare	Synthetic Biology	7/1/2006	University of California-Berkeley	Harward U., MIT, UCSF	23.3 M
	Quality of Life Technology	7/1/2006	Carnegie-Mellon University	U. of Pittsburgh	21.5 M
	Revolutionizing Metallic Biomaterials	9/1/2008	North Carolina Agricultural & Technical State University	U. of Cincinnati, U. of Pittsburgh	14.7 M
	Structured Organic Composites for Pharma., Nutraceutical, and Agri. Applications	7/1/2006	Rutgers University New Brunswick	Purdue University, NJ Inst. of Tech., U. of Puerto Rico	22.0 M
	Biomimetic Microelectonic Systems(BMES)	9/1/2003	University of Southern California	Caltech, UC Santa Cruz	34.6 M
	Sensorimotor Neural Engineering	8/15/2011	University of Washington	MIT San Diego State U	2.93 M
Energy, Sustainability, And Infrastructure	Biorenewable Chemicals (BiRC)	9/1/2008	Iowa State University	Rice University, UC Irvine, U. New Mexico, U. Virginia, U. Wisconsin	14.6 M
	Compact and Efficient Fluid Power	6/1/2006	University of Minnesota-Twin Cities	Georgia Tech., Purdue U. Vanderbilt U., UIUC	21.9 M
	Future Renewable Electric Energy Delivery and Management Systems	9/1/2008	North Carolina State University	Arizona State U., Florida State U., Florida A&M U., Missori U. of S&T	14.9 M
	Smart Lighting	9/1/2008	Rensselaer Polytechnic Institute	Boston University, U. of New Mexico	12.5 M
	Re-Inventing America's Urban Water Infrastructure	8/15/2011	Stanford University	UC Berkeley, U of New Mexico	2.52 M

	Quantum Energy and Sustainable Solar Technologies	8/15/2011	Arizona State University	MIT, Georgia Tech, U. NM, CALTECH,	3.25 M
	Ultra-wide-area Resilient Electric Energy Transmission Network	8/15/2011	University of Tennessee Knoxville	Northeastern U. RPI Tuskegee U.	3.25 M
Microelectronics, Sensing, &Information Technology	Integrated Access Networks (IAN)	9/1/2008	University of Arizona	Caltech, Norfolk Statr U., Stanford U., UC Berkeley, UCLA, UCSD, USC	14.5 M
	Extreme Ultraviolet Science and Technology	10/1/2003	Colorado State University	University of Colorado, UC Berkeley	33.6 M
	Collaborative Adaptive Sensing of the Atmosphere (CASA)	09/01/2003	University of Massachusetts Amherst	Colorado State U., U. of Oklahoma, U. of Puerto Rico	34.0 M
	Subsurface Sensing and Imaging Systems	9/1/2000	Northeastern University	Boston U., RPI, U. of Puerto Rico	36.4 M
	Mid-Infrared Technologies for Health and the Environment (MIRTHE)	05/01/2006	Princeton University	CUNY, John Hopkins U., Texas A&M U., U. of Maryland, Rice University	21.9 M

Table 5 On-Going NSF-sponsored Engineering Research Centers on Campuses across USA

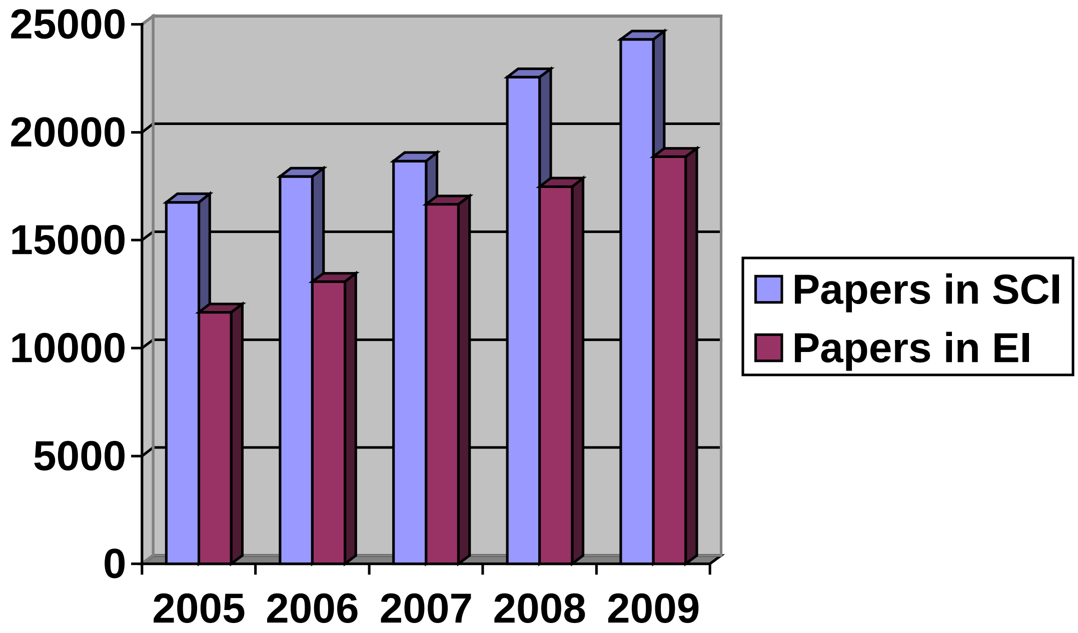
Catagory	Topic	Description	Remarks
BIOTECHNOLOGY	Boi-marker		
	Infective diseases (emerging)		
	Regenerative medicine for the aging population		
	Agriculture biotechnology		
MATERIAL SCIENCE	Nano-materials		
	Smart materials for smart living		
	Advanced electronic materials and devices		
ENERGY	Fossil fuel conversion		
	Next generation solar		
	Green Vehicle		
	Efficient energy endues device		
	Advanced fuel cell		
SEMICONDUCTOR	Highly integrated IC		
	Next generation IC processing and modeling		
	Flexible electronics		
	Next generation computing device		
INFORMATION AND COMMUNICATION	Recognition and interpretation technology		
	Smart enterprise computing		
	Networked multimedia		
	Broadband communication		
	Intelligent transportation system		
	Digital home		
INTEGRATION OF MULTI-DISCIPLINARY TECH	Wireless technology		
	Distributed healthcare system		
	Advanced optical display system		
	Sustainable building		
	Robotics		
	Environment and resource management		
	Precision machinery		

Table 6 2015 Foresight Industrial Tech for Taiwan

Countries	Organization	Established Year	Government Funding Size	Industrial Participations	Remarks
USA	ERC/NSF	1984	Annually, ca.70M US$	Membership Fee:25K$/y Associate Member:10K$/y	Total Number of Sponsored Centers since 1984:48, Ongoing:15
Korea	BK21 Program (Brain Korea)	1999	1.4B US$ (Phase I, 1999-2005) 2.1B US$ (Phase II, 2006-2012)	Phase I (for Univ. Level Excellence) Phase II (for Dept. Level Excellence	Phase I (for Univ. Level Excellence) Phase II (for Dept. Level Excellence
England	Technology Strategy Board	2007	200M pounds	Gov. Announced in Adding Univ. and Industry Links for Phase II	Including Supporting Domestic Small and Medium Companies
Canada	NSERC	1978	46.2M Can. $ (2009)	Industry Matching Fund 67.0M Can. $ (2009)	Budget under the Collaborative R&D with Industry/Innovative Programs
Taiwan	MOE 5Y 50B NT$ Program	2011	50B NT$ From 2011 to 2015	No Announced Plan yet	Originally, for Achieving Centers of Excellence

Table 7 GOVERNMENT-SPONSORED TECHNOLOGY RESEARCHES CENTERS (FOR INDUSTRY)
ON CAMPUS IN SELECTED COUNTRIES

LIST OF FIGURES



Data Sources:
Paper in SCI: National Science Indicators on Diskette, 2010, Thomson Reuters Co.
Papers in EI: Compendex, Nov., week 2,2010, Elsevier Inc., USA

Figure 1 Statistics on Scientific Publications in Taiwan

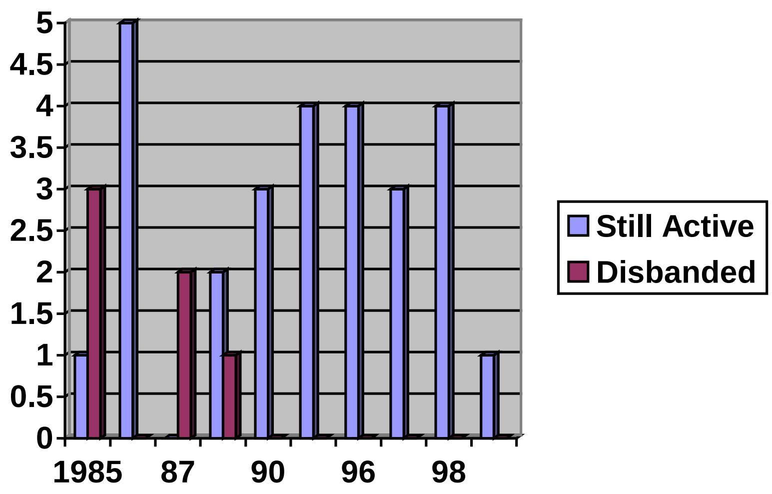


Figure 2 Self-sustaining Graduated ERCs
27 out of 33=82%

Source: Deborah Jackson, ERC 2010 Annual Meeting

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