Academic Innovation –Pitfalls and Strategies

Dr. Shankar graduated with an MBA from FAU in 2000. This was submitted as an essay for a course on Strategic Management. At that time our center was focused on chip design. The focus has since then shifted to systems integration. Many of the strategies in this essay have been implemented at our center, to good advantage. Dr. Shankar worked for Cadence Design Systems during 2001-2002 and supported Motorola divisions in S. Florida. This was undertaken to get a closer professional view of the Motorola design process. This led to a Motorola funded project at our center entitled "One Pass to Production (OPP)." This project aims to reduce the product development time from 24 months (as of 2003) to 24 hours, about a 700 fold improvement. Motorola has funded us to the tune of $1.08 M over the period of 2003-2008 on this project. Many successes have been attained as detailed elsewhere at this site.

A. EXECUTIVE SUMMARY

The gap between the haves and have-nots is increasing. This is true not only for individuals, but also for universities. In the business world, the haves go on to lead the industry, while the have-nots fall behind and wither away. The public universities are being squeezed from all possible directions. A large well-established university can trade on "brand-name" recognition, and even if it falters, it won't go to pieces. The smaller public universities do not have that luxury. In an attempt to be all things to all people, the smaller university loses its effectiveness, direction, and pace of "progress." Here in lie the opportunities and challenges. We have faced the confusing, bewildering, and frustrating maze that an university is. Of course, if you were to accept a machine organization approach, and believed that research publications were the salvation, one would do very well and go on to garner many awards. However, if one believed that the university was a perfect place for innovation and break-through ideas, this would no do. One could say, imagine the access to all those experts. If only we can bring them together, we would be an overnight success and sensation. Most universities, big and small, have not been able to achieve this and certainly we are no different. However, some universities, notably MIT and Stanford, have managed to inject a sense of innovation in to their existence. And they have done well. So, the real challenge for us is: Can we develop a strategy that would help us attract the best faculty members and students, and the most fund from companies and the federal government? Can we publish extensively and yet maintain an innovative environment so as to spin off companies, just like MIT and Stanford have done? What are the obstacles and their remedies? Finally, is this an achievable goal? If so, how do we know we have arrived? How can we perpetuate the success? And how can we learn from our mistakes and do better next time?

In this report, I attempt to develop a blue print for success. I have been with the university system for 18 years and has gone through many kinds of university

experiences. I have had funding from federal agencies, state agencies, companies, small businesses, venture capitalists, and private donors. I have three U.S. Patents and a company is commercializing our research in the biomedical area. I also head a college-level center on tools for chip and system design,. Our center works closely with a few large high-tech companies. Having worked in many different fields, I am able to communicate with professionals in different areas of expertise. My MBA has changed my thought process and has given the ability to develop a plan that is more feasible and synergistic than before.

We have already incorporated many initiatives that would not have been possible until an year ago. The MBA degree has opened a vast array of knowledge that will help me become a better manager and leader. Our center has always had a core group of university and non-university advisors who are committed to the formation of a high-technology center that is a hot-bed of innovation. The informal advisory group has consisted of engineers, professors, university administrators, industry managers, sales and marketing professionals, investment brokers, and management specialists. We have, over the years, explored many different themes for our center, viz., research, alliances with other universities, industrial alliance, teaching, and service. While they are all essential, none of them is appropriate as the central theme. We believe that we now have a unifying vision that is both feasible and forward looking. It is based on the central theme of innovation. We want our center to be the epitome of innovation, constantly thinking and acting in ways that will enhance innovation. Innovation can lead to inventions; research projects, both funded and unfunded; new paradigms in teaching and training; better communication, both within the university and to the outside stakeholders and to the community at large; better public relations; and finally, a stable and exciting environment to work and thrive in.

B. UNIVERSITY – A POWERFUL THIRD SECTOR FORCE

B.1. Background:

A university is appropriately seen as an entity in the third sector, the non- profit sector, that have risen to dominance over the past few decades and address issues that the government and the big business do not address effectively [Druc90]. The non-profit still represents about the same proportion of America's gross national product – 2 to 3 % - as it did forty years ago . But its meaning has changed profoundly. We now realize that it is central to the quality of the life in America, central to citizenship, and carrier of American values and tradition [Druc90]. Its "product" is neither a pair of shoes nor an effective regulation. Its product is a changed human being [Druc90]. Forty years ago, "management" was a very bad word in non-profit organization. It meant "business" to them, and after all, they did not have a bottom-line. But the "non-profit" institutions themselves know that they need management all the more because they do not have a conventional "bottom-line." Universities do get subsidies and grants from the state and federal sources. But increasingly they have to seek out donors, or more appropriately the contributors as Drucker calls them [Druc90]. The contribution of the American people to non-profits has stagnated around 2 to 3 % of GNP for more than 40 years. As a

second major challenge, the non-profit has to learn to give community a common purpose. The volunteer, or unpaid staff as per Drucker [Druk90], should be made to feel that they are contributing to the community and their efforts are appreciated. Our university seems to have been fairly successful in raising awareness of our university in the community and in seeking major donations. However, these donations are focused away from many currently existing initiatives, and serve to dilute the resources further, thus threatening the existence of many non-endowed centers.

Mintzberg [MiQu96] considers a university as a professional organization. Such an entity is primarily organized around experts, as with hospitals, research centers, consulting firms, space agencies, biomedical companies, and, of course, universities. Organizations of experts seem to divide themselves into two somewhat different contexts. In one, the experts work in rapidly changing situations that demand a good deal of collaborative innovation (as in biotechnology or semiconductor fields); In the other, experts work more or less alone in more stable situations involving slower-changing bodies of skills or `knowledge (as in law, university teaching, and accounting). The second type, the so-called professional organization, a bureaucracy may exist without centralization. This happens when the work is complex, requiring that it be carried out and controlled by professionals, yet at the same time remains stable, so that the skills of those professionals can be perfected through standardized operating programs. This is common in universities, general hospitals, public accounting firms, social work agencies, and architectural firms. It hires duly trained specialists – professionals for the operating core, then gives them considerable control over their own work. Training, reinforced by indoctrination, is a complicated affair in the professional organization that is done on-the-job. As new knowledge is generated and new skills develop, of course (so it is hoped) the professional upgrades his or her expertise [MiQu96]. All that training is geared to one goal, the internalization of the set procedures. This however differs from a machine bureaucracy in one major way – while the authority is hierarchical in a machine bureaucracy, here the authority emanates from outside, that is the self-governing associations of professionals from various organizations practicing the profession. These associations set university standards, which they ensure are taught by the universities and other entities practicing the profession. The outputs of professional work, however, cannot easily be measured and so do not lend themselves to standardization. Imagine the quality of the amount of learning that takes place in a classroom.

At the operational level, a professional organization is a set of standard programs – where the portfolio of professionals' skills are applied, first to categorize the client's need in terms of one of the programs or options, and to apply, or execute that program. It is in this "pigeonholing" process that the fundamental differences among the machine organization, the professional organization, and the innovative organization can be seen. The machine organization, such as a manufacturing plant, is a single purpose structure. Presented with a stimulus, it executes its one standard sequence of programs. No diagnosis is involved. In the professional organization, diagnosis is a fundamental task, but one highly circumscribed. The organization seeks to match a predetermined situation to a standardized program. Fully open-ended diagnosis – that which seeks a creative

solution to a unique problem – requires the innovative form of organization. No standardized contingencies or programs can be relied upon here.

So, how could such a professional organization with this high degree of freedom and respect go astray and cause much anguish? It happened recently in the medical world, when HMOs took over and demanded that the medical doctors and other medical professionals abide by their rules and regulations. Typically, it is the outsiders, as with HMOs, that cause the professionals' autonomy to be compromised. The higher administration at an university are expected to woo outsiders, such as legislatures, community, donors, and industry, to support the organization, both morally and financially. And that often leads the outsiders to expect these administrators, in turn, to control the professionals, in machine bureaucratic ways. In case where the organization is dominated by skilled workers who use procedures that are difficult to learn yet are well defined, that is the situation is both complex, stable and amenable to rationalization, there evolve standard procedures. This happens at universities where there may be a perception of a stable professional skill base. Put another way, the university might move towards a machine organization structure and reward obsolescence and not skill upgrade.

However, if the situation is complex and not amenable to simplification, the organization might be driven toward multidisciplinary teams and an innovative form. A typical doctoral granting university sees both these forms of organizations existing as a modification of the professional organization. While an elite research university may continue to feel somewhat healthy tension due to the existence of both these forms, the second tier universities face a different problem: a struggle to overcome the dominance of a machine organization imposed on them because of the outsiders ("teach more classes that are bigger") by moving up the ladder in terms of Carnegie research rankings, lest they lose their ability to do any research at all. In an elite university, the research aspect is a given, and innovation is feasible, once again brought about by constant involvement of outsiders to facilitate the same. At a second-tier university such as ours, there is less of an opportunity to think of innovation, when our own existence as a non-machine organization is at risk. But clearly, so long as we continue in this indeterminate state, innovation can be practiced. However, as the author can attest to it, do not expect the system to allow entrepreneurship! The bureaucratic control can kill any entrepreneurial spirit and compromise the goals beyond repair. Thus, as we continue to struggle and evolve an innovative organization in a second tier research university, we do not have any illusion that entrepreneurship can prosper whether at this university or any other research university. That would have to be conducted in a spin off.

So, first, let us understand the issues that a university and its professors face.

Cole et al. [CoBa94], list many dilemmas that US Research universities face, that are similar to ours: How does an university define their priorities? Whose "truth" shall the university support – a nonchalant commitment to a position might shift the "truth" farther away? How to reshape a reward system, which has swung too far in favor of research, to support teaching, while not impairing research – perhaps by emphasizing quality

research? How does one gain more share of the dwindling federal support dollars while the cost of conducting pioneering scientific research are escalating? How will the university's commitment to open science is affected by their relationship with both foreign and domestic businesses? Is the nineteenth-century Germanic model of department and school boundaries ending? Add to it the additional pressures at second and third tier universities: Legislative pressure to increase enrollment and productivity; Administration's pressure to move up in research rankings; Low morale and confusing signals; Lack of "brand" acceptance by other stakeholders, such as the community, local industry; and donors; and politics of acquiring scarce resources and rewards.

Surely, no one in their right mind wish to be caught in this impossible mess. However, consider the positive factors: Ability to strike their own balance among teaching, research, and service, as they wish, once they have acquired tenure, provided they understand the risk and rewards of making those choices; The joy and satisfaction of shaping and directing the career development of students; An opportunity to follow their favorite causes and research issues, with or without funding; A relatively stress free life that allows flexibility and tradeoffs in income against leisure/scholarly time; and finally, we might add, an ability to mix with other experts on campus and develop innovative ideas to the benefit of all – the university, faculty, students, and community.

A Center within a university as a focus:

The non-profit organization exists to bring about a change in individuals and in society. Given that the overall objectives of the university as teaching and research, should our center, a non-profit sub-entity within the bigger organization with its access to both government and private funds, continue to subscribe to the same objectives and depend entirely on the bigger entity to do the "right thing"? Given the politics and the scarce resources, that would not do. Consequently, many centers such as ours tend to focus on research and service grants from the government and industry sources. However, this can be very inconsistent, especially for second tier universities. So, innovative solutions are called for to seek new ways and contribute to "change in individuals and in society."

At the larger universe level of a university, there is much pressure to "Perform." This is compromising the traditional roles of a US university. There is accountability pressure from the stakeholders and competitive pressure from for-profits that have staked out lucrative segments of the "business" just as Federal Express and DHL were able to do with the US Post Office. While the elite universities will continue to be perceived and supported as pillars of excellence, the second tier research universities, staffed nevertheless with competent faculty members, are sliding backward in comparison to these elite universities. So, in a sense, depending on the larger entity of a university to support a center unequivocally is not feasible and beyond any realistic expectations.

So, we leave this section with one important thought: That we, the faculty, are at a university because we are content with the tradeoffs. Criticizing the system for lack of direction is counterproductive. However, the system provides sufficient flexibility to allow innovation. Innovation can be the key objective around which we can develop our

center. A successful innovation can be spun off into an entrepreneurial non-university entity. A non-successful innovation can be published, and documented in public domain, as a research project, and when completed, into a teaching example or case study. Thus, Innovation, properly practiced and implemented in the university environment, can be the key to successful balance of the three aspects. However, one central thing must happen: there should be genuine motivation and desire for the professionals, both faculty and staff, to participate in innovation. The departments and colleges cannot be expected to consent to innovation as an official assignment. However, strong and motivated faculty members can decide to come together and drive a sub-entity at least towards innovation and benefit to university and self.

Innovative product development at universities as an attempt to compensate for diminished government funding has been well explored at other universities [SlLe97] with uneven results. We did not see any methodical approach to facilitating and implementing such a change at an university, in perusing this book. We, however, will study other universities further and seek best practices.

B.2. Strategic Group Map

To understand this, we draw a “value net” for our center from a similar one drawn for universities in a book entitled Co-opetition [BrNa96]. The authors use game theory to move beyond overly simplistic ideas of competition and cooperation to reach a vision of co-opetition more suited to the opportunities of our time. As the book describes it, business, in our case a non-profit business perhaps, is both War and Peace. Mere acceptance of one or the other does not lead to a thriving organization. If one looks at a business as a game, then who are the players and what are their roles? The knowledgeable response today might be: Customers, suppliers, and competitors. Add one more category to create the value net: people who provide complements, or complementors as the book calls them.

Along the vertical dimension of the Value Net are the company’s customers and suppliers. Resources such as raw materials and labor flow from the suppliers to the company, and products and services flow from the company to its customers. Money flows in the reverse direction, from customers to the company and from the company to the suppliers. Along the horizontal dimension are the company’s competitors and complementors. Very succinctly, from a customer’s perspective, a player is your complementor if customers value your product more when they have the other player’s product than when they have your product alone. On the other hand, a player is your competitor if customers value your product less when they have the other player’s product than when they have your product alone. Customers care about the end result, not about whether the company that gives them what they want happens to belong to one industry or another. On the other hand, one should also look at this from the suppliers side: A player is your complementor if it’s more attractive for a supplier to provide resources to you when it’s also supplying the other player than when it’s supplying you alone. A player is your competitor if it’s less attractive for a supplier to provide resources to you when it’s also supplying the other player than when it’s supplying you alone. As we continue moving into the information

economy, supply-side complementarities will become increasingly the norm. There's a big up-front investment in learning to make something – whether computer chips or airplanes – and the variable costs are relatively modest. There's huge leverage. The more people that want a knowledge-based product, the easier it is to provide. Note that customers and suppliers play symmetric roles. Competitors and complementors play mirror-image roles.

Thus for our center, we can identify the players as:

- Customers – Students, Parents, Federal Government, State Government, University, Companies, Donors, Volunteers/Contributors, Alumni.

- Suppliers – Faculty, Staff, Administrators, Publishers (books, journals, online services), Caterers, Community Colleges, Venture Capitalists.

- Competitors – Other Colleges and Centers, Fabless CAD-Design Centers (commercial), Freelancing Faculty and Consultants, Private Enterprise, Training Institutes, Hospitals, Museums.

- Complementors – Other Colleges and Centers, K-12 Education, Computers, Housing, Airlines, Hotels, Local Employers, Copy Shops, Investment Community, Industry Participants (paid/unpaid), Large Companies (their patent portfolio), Large Universities (their continuing education programs).

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Notes: NSF provides many mechanisms to establish national centers of excellence or more regional industry-university centers. The former may be out of our reach, as they are focused on cutting-edge basic research, while our focus is more on applied research and development. We should certainly work to build consensus for an industry-university center. This, however, will require at least 3 years.

B.3. Competitive Position

- **A state-of-the-art infrastructure**: We can boast of a state-of-the-art Center in VLSI and Systems Integration (CVSI) that was formed with the help of Motorola. The center at its best had $57 million of tools and equipment which together made it one of the best such facilities around the nation. Till now, the primary beneficiaries have been the students, with the center struggling to exist. However, many of our recent initiatives on addressing the customer needs in a judicious and focused manner have changed the dynamics. As an example, we will develop training material for companies based on their technological needs. We will only train those students (at a nominal fees) who are interested in learning such advanced skills. We will not make learning these skills a mandatory exercise for all students – the latter involved tremendous resources with no avenue for recovery from the department and also caused resentment among students.

- **A multi-disciplinary, college-wide center:** VLSI (Very Large Scale Integration), the art and science of making integrated circuits or electronics chips, is inherently multidisciplinary. In fact, some universities have seriously considered developing whole undergraduate programs around the concept, just as biomedical engineering has evolved, another multidisciplinary area. Eventually, many schools formed a department of biomedical engineering, but that has not happened in the VLSI area. Perhaps the time for it has come. Last summer, we proposed a cross-disciplinary program in bioengineering, in collaboration with the college of science. This program has been approved by the Board of Regents. For VLSI, we will start building graduate programs in VLSI and then work down to develop an undergraduate program.

- **Our Complementors:** A "complementor" enhances the value of one's product in the eyes of a customer, and persuades a supplier to perceive one's entity more favorably [BrNa97]. We have alliances with many entities both within the university and outside that will enhance the values of both. As an example, we have developed proposals recently in collaboration with the colleges of education, business, and science. We have also submitted proposals in the past to NSF that brought forth a proposal to integrate design tools and methodologies across the stages of a high tech product development: design, packaging, and manufacturing. This proposal was not funded. However, we have established a good working arrangement with them.

- **Differentiation Strategy:** We have, over the years, attracted many highly talented and innovative faculty members to participate. These are not typically the top research producers, but hands-on, pro-active members who would like to tackle new challenging issues with much energy. They typically have several patents to their credits, have industrial experience, and may have participated in one or more successful businesses. The center respects them and would like to make them more valuable to the system, by helping them become also fairly prolific research producers. But beyond that, we wish to utilize their attributes in

building a center for innovation. Our goal is to build expertise in translating consumer needs into prototypes rapidly. Subsequent to that other organizations may get involved to develop commercially viable products. However, to the extent we can, we wish to involve packaging, manufacturing, and marketing experts, in addition to domain-specific experts, in the group [Joll97]. Our goal is also to build many such fabless design centers, or more appropriately, build the expertise on a global basis and part-take in the benefits that would accrue worldwide. First, we want to train them, and then , we want to recruit the best from the lot to establish design centers and also train others. Our work represents the highest entry barrier domain in the entire silicon industry and we are rapidly consolidating the lead built over the past 5 years.

C. ENVIRONMENTAL SCAN

C.1 Opportunities:

- **It is a period of rapid change:** Our center's chosen domain , Engineering Design Automation (EDA), represents the fastest growing area within the fastest growing industry, viz., the semiconductor industry. Some of our graduates have gone on to become millionaires, after 5 to 6 years in the field. The domain thrives on solid progress on which the remainder of the industries depend critically upon. It is not a flash-in-the-pan successes of Internet. EDA is the fundamental building block for the semiconductor industry. One might wonder how we could exploit opportunities in this area while being situated so far from Silicon Valley. Actually, many of the innovations in our technology domain have come from the UK. We believe the reason is that they were able to focus on fundamental issues, being far from the hype, and see new avenues. We believe that we can accomplish the same, given that we do have access to experts in many related fields, at FAU, Motorola, and elsewhere.

- **Technology facilitates innovation – Expertise is the entry barrier:** It is very expensive to assemble an array of experts, as some of the new IPOs, such as Analogy Inc., in the field have found. We, on the other hand, have access to almost equally competent experts, at FAU and outside, whom we do not have to support fully.

- **Industries need to retain their employees – there is need for a good local university:** The unemployment in the US has hit a record low. Many engineers and software professionals are being recruited from foreign countries, such as India, Russia, and Eastern Europe, to meet the demand. So, no high-tech company can afford to lose their talent. In addition, they need to recruit new professionals. All these professionals will look for good educational environment both for their families and themselves. We have started offering programs targeted to different levels of professionals. Also, unlike trainers from companies, we are available locally and it is easier to schedule additional courses with us.

- **Industries cannot keep the good designers- an opportunity for students and faculty:** Top designers have many offers, for companies can be built around them. Many top designers at Motorola have left for much greener pastures. This creates an opportunity for faculty and students to participate. However, we have to overcome the bias against a local university. Many managers at Motorola now prefer hiring FAU engineering students, for they know they are good enough or better than others, and will stay in the local area in the longer run.

- **Industries are facing severe challenges in shrinking product cycle time:** New engineers that they recruit do not have the luxury of 6 months to get up to speed. Motorola would like them to become productive much sooner. So, either they hire our students who may already be trained with those skills, or have these new recruits take especially designed courses from us. We are negotiating training contracts on this at present.

- **Third world countries are a few steps behind the developed countries:** Our domain is especially well suited for establishment in many less developed countries. We use computers to design new high-tech products. About 90% of the design can be completed just sitting in front of a computer, just like the software programmers. The remainder 10% can be shipped off to companies in Taiwan and Korea, where they have built up a marked advantage in chip fabrication. Post fabrication testing is one area that has not been well addressed and as such, is an opportunity. Going beyond that, training engineers in Korea, Taiwan, Japan, and West European countries is clearly needed today. In two years, this will be equally well demanded in countries like India, China, and Brazil. We envision a day, in the near future, when people with engineering background can set up a computer in their house and design a new consumer product. This is clearly feasible today – the only hindrance is the high cost of software. As the EDA software industry moves to PCs (from UNIX systems) and allows short-term licensing, that will change. Note also that systems with older technologies are just fine for many applications. There is no need to build the world's fastest system, when all it needs to do is count the number of visitors to a shop. Thus there may be an opportunity to keep old fabrication lines functioning. Most industry leaders continue to scrap such older facilities and build the facility for the smallest transistor size, since that has the highest margin. But, as Christensen points out [Chri97], a disruptive innovation is actually simpler and unwanted by the mainstream customers. In addition, the new customer is not large enough for the industry leaders to be concerned with. The needs of less-developed countries to use such older fabrication lines falls in this category. However, just imagine selling 100 million units of a new, slightly bulky, product in India. That could make the company. In fact, WIPRO in India has exploited this strategy and has become immensely successful very quickly.

- **Most funding opportunities are multidisciplinary:** Most issues to be tackled today are cross-disciplinary and needs active input of the experts. However, the key is that such experts should understand enough of each other's fields that they

can converse intelligently and make decisions quickly. This is precisely what we want to develop at our university.

- **Global reach of the Internet:** Internet is not just a media to help us train engineers elsewhere in a more productive manner. It is also a media for developing collaborative relationships, as software developers have done with India. Many EDA companies also have established partnerships in India. However, our objective is in establishing alliances on product design. There are many outstanding issues such as security, piracy, patent rights, and legal limitations, that may hamper the progress of the first few.

C.2. Threats

- **Accountability measures from the legislature:** We may become a teaching institution, given the dynamics of the legislative initiatives. If so, the faculty members will lose their time & ability to conduct research. The faculty will be out of touch with the latest issues. They will not be able to contribute to most of the innovations. The center would cease to exist in its current form. The choice then may be to take it private. The legislative action may not come for the next few years and that gives us breathing period to develop the idea.

- **Industry funding is inconsistent:** We have focused on industry collaboration since 1994. When the paging industry did well, during 1994-1996, our center was funded well by Motorola and Harris. However, our fortunes declined together with those in the industry that we supported. Now, we have evolved a multi-pronged approach – of building collaborations with other colleges and seeking federal, state, and private funds.

- **Rapidly changing and increasingly complex technology:** This is precisely the reason why many universities have shied away from the daunting task of integrating the EDA tools across the many disciplines. The reason is that the EDA tools are constantly getting updated and there is enormous effort needed to keep up with the changes, update the training course material, and still go on to do be productive at an university. We have chosen, of late, to focus on fewer tools, distribute the responsibility to different faculty members, and move to PCs to support the classes. The extra effort to learn the latest tools will be restricted to those areas in which the industry wishes us to develop training material. We do not believe that innovation always needs the latest in technology. We are able to make this confident statement after chasing the technology trends for a few years, and developing products that did not need any of those advances.

- **Community Level:** The local community already sees us as a teaching institution ranked low in research. The perception comes from long-held beliefs, but is reinforced by our university's inability to project faculty members as assets of the community. Donations are obtained to support eminent chairs, while the rest of the faculty members are relegated to a low status. There needs to be an attempt to

educate the public. Otherwise, the university would have put their eggs in few baskets only and would have failed to exploit to advantage the capabilities of the majority of the faculty members. For our part, we do intend to project our faculty members to the public and generate excitement about this group.

- **Government Level:** NSF recently came out in favor of larger and longer period grants, focused more on basic research. The larger institutions will be the beneficiaries of this move. The trend is such as to increase the gap between the haves and have-nots. However, this begs the question: Did every company that started out small need a federal subsidy to survive and thrive? How come universities must and should depend on federal dollars to survive? Why that is the only measure of an university's research capability? Why royalties and industry contracts are not considered part of the total? If we do not subscribe to this, the center's existence is threatened, even if it brings in millions of dollars in revenue from other means. However, it is interesting that this turned out to be a non-issue. Our emphasis on innovation naturally leads to ideas that are amenable to research, as two recent proposals, one each to the Department of Education and NSF, can attest to. Brainstorming among a group of colleagues, with a constant background evaluation of our strengths and project feasibility, led squarely to these two projects. We have not been funded on either of them, but we are confident that this is the right way to succeed.

D. CENTER

D.1 Strengths

- See section B.3 on Center's Competitive Position. Only one more is added here.

- Good Industry and Business Network: We have built up a good network of engineering professionals at companies (some of them are our own Alumni) and professionals in business domains (financial, legal, investment, patenting, venture capital, training, and marketing). Our biggest challenge is to make progress, communicate the same to our stakeholders, and seek their active participation.

D.2. Weaknesses

- **Student Level:** Most engineering students wish to graduate quickly. We do not blame them, for they believe that all they need is a degree. But we have had many students who went on to become extremely rich or valuable to the company. This happened because they took time to identify what the industry needed and made sure that they picked up that background before they graduated. Most often it is a computer that scans the resumes and searches for key words in those resumes. However, most students do not know this and are sorely disappointed when they get an entry-level job after their graduation. We are attempting to educate the

student so they can make the appropriate decisions. We have also decided that we just want to expose the student to the minimum set of tools and if they truly wished to learn more, we will ensure that via senior projects/DIS/ short courses.

- **Faculty Level:** The tenure process of emphasizing the quantity of research papers moves faculty away from any hands-on work. Most faculty who prefer hands-on work do not get promotions. Most senior full professors do not know how to do hands-on work. Unfortunately, this problem exists at all universities. Our center has attracted the hands-on kind because they find satisfaction naturally in building things. However, we also invite other faculty members to participate, and show the way – that they would have to learn a tool or build up an expertise, as appropriate. Some faculty members do build up that type of background and become productive members of the team. It is a slow process, however.

- **Department Level:** The departments are very aware and protective of their boundaries. Since the departments need to show productivity in their own department, the faculty are not encouraged and not well regarded if they pursue areas that help the department less. The boundary issue will not go away, as we have realized to our disadvantage over the past few years. However, this has given way to a more cooperative demeanor. Recently, we recommended to the university technology transfer committee that the department and the college receive part of the royalty payments, thus creating good will at both the places. This will also make it possible for the departments to allow faculty to participate in cross-disciplinary projects. *This has since then been implemented by OTT/FAU – Shankar, 2008.*

- **College Level:** Industry representatives would prefer to deal with the college level officials, to avoid confusion and misunderstanding that might result if they dealt with others. However, on many an occasion, the college leadership is busy with so many other details that they may not be able to pursue industry relations effectively. Also, it may not be appropriate for a Dean to go and visit all and sundry. Thus, there is a role for centers such as ours. But the old boundaries make it difficult to chart a way out of the university. We hope that, as the departments continue to see larger streams of income from centers such as ours, the departments and the college would accept our existence and allow us to be pro-active.

- **University Level:** The university has a set of goals that may not match the goals of individual colleges and other sub-units in the colleges. However, it is our experience that it is appropriate to align oneself with the overall goals of the university. Make every attempt to keep the higher-ups informed and focus on issues of relevance to them. Seek each objective at a higher level as a challenge to address and a problem to evolve solutions for. We recently submitted a proposal to FAU on Distance Learning that took advantage of our capability in proposing a

method to implement team learning on the web. One other item to note: University goals are not pro-industry.

- **Center Level:** The center has seen both good and bad times. Inability to understand the university dynamics and sudden reversal of fortunes led to enrollment in this MBA program. I have learnt much from the MBA program and we have started instituting many innovative ideas as a consequence. They are detailed below. Some of the major issues are: a fairly large ($100K) operational budget; poor track record; and faculty non-involvement beyond the boundaries of their departments.

- **Tenure, politics, and poor performance measures tend to destroy motivation:** This is a typical university. Values at a university have evolved over many decades. These values have stood the test of time. It is true that many of those values are under attack today, but as Cole et al,. [CoBa94] indicate there is little likelihood that anything would change substantially over the next decade. We act with the full realism of what we can change and what we cannot change. Thus, we wish to help younger faculty members to get tenure, by providing resources so they can publish papers and grant money. And we wish to challenge older faculty members to seek more ways for professional and monetary returns. Performance measures may get changed once we have convinced many faculty to see the benefits of innovation – that it can be the central theme for improving teaching and getting more research funds. And of course, some of those ideas can go on to provide decent financial return to the faculty member involved.

- **There are strong perceptions of boundaries and a zero sum game:** Departments feel that a center such as ours is usurping their territory. However, the threat of external forces, such as Distance learning programs from other universities , is much bigger. And If we do not meet the needs of a local company, they will have no alternative but to go elsewhere. Unfortunately, if one is not pro-active, such opportunities will be missed. We do not know how to resolve this problem. The industry grants do not provide much excess cash to distribute among other units.

- **Revenue channels are limited:** Funds to the university can only flow through the Division of Sponsored Research, FAU Foundation, FAU Research Corporation, and the Division of Continuing Education. Due to fiscal reasons, the centers are not allowed to generate their own revenue channels. This is no longer an issue for us, but it was frustrating initially, when some of the main entities did not seem to know their own domains well. This, however, has changed.

- **High cost of maintaining the design tool infrastructure:** Our software and hardware tools for EDA are very expensive. We will need $100K per year just to keep the tools running. This is too much money to seek from the university. We have obtained much unconditional support from Motorola over the years. But now the Motorola players involved are different. Now, thanks to MBA, we have

developed a strategy for support from Motorola that is closely tied to a two-way long-term relationship.

E. RECOMMENDED AND IMPLEMENTED STRATEGIES

- **Nurture an environment of innovation.** Encourage faculty and students to think "innovation" in all their endeavors. Provide avenues to translate their ideas into products, patents, and commercialization. There are several mutually complementary concepts and theories in TQM (Total Quality Management) [SiMo95, LeCo99], TOC (Theory of Constraints) [Smit00, McMu98], TRIZ (Algorithm to translate innovation to a product) [Alts99], and Senge's Learning Organization [SeKl94]. We provide a brief discussion on these in Appendix B. We have done much work on TOC, in collaboration with Dr. Janice Cerveny, Business. We are working with experts on two other topics – TQM and TRIZ at present. We hope to integrate the ideas over the next two years. Similar Skunk Works have existed in other entities [Katz97] but would typically disband with the team members moving on to other projects later. However, the university provides an unique opportunity to involve faculty members on a continuous basis in such Skunk Works. We believe that Concept Mapping [Nova98] is ideally suited for developing the current understanding of a field and identifying missing links in the thought process, which then becomes topics to explore and find innovative solutions with.

- **Develop new learning modalities:** Distance, Industrial, and Global. This is an area we are exploring very aggressively. Courses in our high tech area, especially those that couple theory, tools, and design examples, are rare. We have developed such courses for Motorola in the past and they were very successful. We expect to do the same to different targeted markets, both in the industry and in other countries. A complete web-based program has not been successful in engineering. We will eventually evolve a CDROM/Web-based program that will have a strong component of a teacher's presence and participation. Davis and Davis [DaDA98] detail seven different strategies (behavioral, cognitive, inquiry, mental models, group dynamics, virtual reality, and holistic) for teaching and learning. We will study the approaches and adapt the best practices possible.

- **Develop new performance measures and rewards:** As TOC (Theory of Constraints) has shown, local optimizations may not lead to global optimizations. The reverse is also true that global optimizations may not lead to local optimizations, as has happened in my specific case. FAU has received $500 K in royalties for licensing my biomedical patents, of which none came to my department. The department took away my lab space! We are attempting to change this ironic state of things. But we also recognize that with this emphasis on research and teaching, innovation will be discouraged and even, unintentionally, penalized. So, we will have to come up with rewards for thinking "innovation." Of course, if their concept succeeds in the real world, they will benefit monetarily. But not every idea will go that far. So, we need to develop

incentives, while we work to change the performance measures in the university. We hope that if enough faculty succeed financially there may be a movement to change the local measures.

- **Align with university goals and address public relations:** FAU has identified several strategic directions in its latest document on mission and goals. Primarily among them is the easy reach of education to all and research enhancement. We will direct our innovation efforts to determine how best to offer engineering education at low cost and at remote sites, perhaps using web. Our goal is to help FAU, while at the same time, we develop innovative products that we can commercialize. FAU then becomes our partner in evaluation, and will be one of the first beneficiaries. We will cultivate the media and seek their input in developing programs that would be of interest to the community.

- **Evolve synergistic diversification:** We already have collaborations with Colleges of Education, Business, and Science. We have approached them and evolved collaborations, putting forth our capability as a complementor for their own. These were projects proposed by us and developed in collaboration with the faculty from these colleges. As we succeed, we will use these cases to acquaint other centers and colleges about our capabilities.

- **Develop a center of excellence with a virtual alliance:** We have spent nearly two years in submitting proposals to NSF, in collaboration with other centers that have complementary strengths (in packaging, manufacturing, and software engineering) at other universities. Unfortunately, without an individual track record of excellence, NSF could not see a joint center taking shape to address bigger things. We have learnt that the hard way. Our focus is now to develop an outstanding track record at our center, and seek the collaboration of other centers as needed. A joint center of excellence may not materialize soon. There are several refernces on this. Davidow and Malone [DaMa93] describe the various types of potential alliances that can develop by discussing the various global trends. Linpack and Stamps [LiSt97] on the other hand, give a step-by-step guidance on how to establish such a virtual center and succeed. The recent book of Pasternack and Viscio [PaVi99] of Booz.Allen- Hamilton consulting company discusses how people, knowledge, and coherence are essential for a virtual collaboration to thrive. The Center in their vision literally may not exist or would exist with very little power and shrunk considerably from a typical central office of today's organization. We reproduce a summary of their thinking in Appendix C. While we are attempting to implement their ideas in our center, we do not have such a say in the operation of collaborating centers, at least not yet. We will tackle this after a few years, once we have better established ourselves. Slaughter and Leslie [SlLe97] predict that NSF will only fund Government-Industry type of centers in the future. We will work to build an unique capability among our universities, in engineering design automation, that most universities have shunned, because of the high cost of maintenance and rapid change in technology. We have managed to keep abreast of changes for the past five years and we think

we will be able to keep current and build on recent advances. Thus, an NSF center of excellence, after 3 to 5 years is a possibility.

- **Build respect for non-traditional faculty members:** Traditionally, universities heap awards on prolific (basic) research paper producers and ignore the contributions of faculty who are hands-on and applied research oriented. Robert Maslow's Needs Hierarchy model [Masl98, HeSl98] has five levels of needs – a lower level need is to be met to strive for the next higher level. The five levels of needs, from the low to high end are, respectively, Physiological, Security, Affiliation, Esteem, and Self-Actualization. Most faculty members have met their first three needs and are short-changed in the fourth stage on esteem building. It is our desire to help them gain the esteem they richly deserve so they can strive to self-actualization. We hope it will reflect as innovation, either as the singular goal or one of their many goals for self-actualization. We wish to give such faculty members every opportunity to shine at the center, by helping them publish papers, file patents, and develop innovative products that will provide financial benefits to them and the center. We will also publicize their contributions to the community so the community is better informed. We intend to this by having free seminars on "Technology Simplified," as a first step. This stage of Esteem Building should go a long way in tapping into their unrealized potential. Recently, because of our efforts, the Provost agreed to allow engineering faculty members to seek market prices for their training courses. Prior to this, we could only get paid at our faculty rate.

- **Build a Track Record:** On many an occasion, we are compared to better known institutions and disparaging comments made. More importantly, we get denied support. So, we have to make a conscious and concerted effort to build a track record. Our web site already includes a large set of good designs. As a next step, we will encourage faculty members and staff members to co-author books. In our domain area, Engineering Design Automation (EDA), there is a dearth of such books. EDA would be glad to buy many copies of such books and give away to their potential customers. So, the market is clearly there and is expanding rapidly. We can use this avenue to build a track record. In addition, we will get our training courses approved by the Continuing Education programs at various well-known universities and professional organizations. This is relatively easy, but adds much to the public's perception of our competency.

- **Build communication and a process for change:** Smith lists ten management principles [Smit96] that focus on managing people and performance both at an operational level and on a longer horizon, in terms of behavioral and skill change to focus on the immediate and intermediate level objectives. We wish to give one and all the freedom to explore their interests and ideas. But, first they need to be productive members of the group, so the entity can survive, thrive and support their innovation. For this, we would have to follow certain management principles. This involves communication and change processes of various kinds – including the objectives, performance evaluation and feedback, behavioral and

skill change, team dynamics, delegation and responsibility taking, honest discussions, and consistent behavior from the leadership.

- **Build the organization to last:** Some may feel that the world needs to be shown how indispensable they are by letting the institution they built go to ruins as soon as they leave. However, that is not fair to all the others who participated and made the center a reality. It is our intent to build a center that will last a long time. Thus, we will incorporate and disseminate best practices. Our web site will always be up-to-date and contain much useful information, as it does indeed today. We will make all the course material available to other faculty members so they can teach the same easily. More importantly, the students will see a consistent syllabus covered and will have more faith in our program. We will publicize even "minor" innovations, for they may be the stepping stones for bigger innovations, either because of the concept itself, or because the innovator has gained in confidence. Beyond that, we subscribe to the ideas put forward by Collins and Porras [CoPO97] and Matheson and Matheson [MaMa98]]. The first analyzes the successful habits of visionary companies. Succinctly, they are the following: 1. Be a clock builder – an architect – not a time teller. When the historic Constitutional Convention was held in 1787, the question was not who should be our president, but what process we should incorporate to ensure that the institution would last much after they are gone; 2. Embrace the genius of "And.". Learn to accept and thrive on two seemingly contradictory forces or ideas at the same time – like the yin/yang symbol from Chinese dualistic philosophy. As Scott Fitzgerald pointed out, "The test of a first-rate intelligence is the ability to hold two opposed ideas in the mind at the same time, and still retain the ability to function." Allow healthy tension to exist; 3. Preserve the Core and Stimulate Progress. Profitability is a necessary condition for existence and a means to more important ends, but not the end in itself for many of the visionary companies. Profit is like oxygen, food, water, and blood for the body; they are not the point of life, but without them, there is no life. Profitability is not a core value for such companies. All have an ideology and build up on that ideology; 4. Seek consistent alignment. Sweat the small stuff. It is not one big idea that will make or break your entity, but a lot of little details. People want to believe in their company's vision, but will be ever watchful for the tiny inconsistencies. Matheson and Matheson, on the other hand, talk about the importance of the process over action. At the operations level, speed and action are important, but at the strategic level, process is important. They advocate a hierarchical model of R&D that matches the corporate model: Corporate level – R&D Technology Strategy, Portfolio Strategy: R&D Portfolio Strategy; and Project Strategy – R&D Project Strategy. The idea is to keep options open and seek better commercializable solutions, instead of being locked into one, possibly flawed solution. They list nine principles of R&D as: Systems Thinking; Embracing Uncertainty; Outside-In Strategic Perspective; Open Information Flow; Disciplined Decision Making; Alignment and Empowerment; Creating Alternatives; Value Creation Culture; and Continual Learning.

- **Encourage business spin-offs:** MIT and Stanford have been highly successful in allowing their staff and faculty members to spin off businesses [Robe91, Saxe96]. Roberts [Robe91] details the MIT environment that spun off 156 companies by 1991. Saxenian [Saxe96] persuasively shows how companies in Silicon Valley succeeded using horizontal integration across many companies. On the other hand, the Route I28 companies in MA failed because of their vertical integration and lack of fresh ideas (through interaction with others outside their organization). We wish to combine the wisdom from both these approaches. However, we do have one thing very different from MIT, apart from its stature as a premier institution: MIT does not seem to officially expect any royalty payments from these companies. To date, MIT has actually benefited more from their generosity than other universities have succeeded in gaining through their royalty sharing plans.

- **Have all stakeholders participate:** have open houses for parents and students alike to show what is possible through the center. Invite FAU administrators and Industry leaders for show and tell. We have already developed our website into one of the best at FAU. It is full of information, so much so that, a Korean engineer signed up recently to come and spend 6 months at CVSI. Mail a quarterly letter with useful information and happenings at the center to the stakeholders. Invite industry engineers and managers to talk to students and faculty members.

- **Be in the limelight:** Release news of activities to newspapers. Set up design contests; Have the industry engineers judge class designs. Invite FAU administrators to observe the results.

- **Serve the community:** Develop "Technology Simplified" Seminars. This is a project we wish to start with an investment brokerage, as per the suggestion of Dr. Jerry Smith, Business. The intent is to simplify the technology so investors, innovators and entrepreneurs can understand and use the information. Our hope is that this will introduce engineering students to some real world problems, so they can get involved and actually help develop products. Of course, if we are able to help some investors make the right decisions, the good will and news coverage will help tremendously.

- **Forget about being the best in research. Build on the advances of others (Part I):** This is strictly based on the realities of the high tech research. Very few research institutions with highly developed labs and complementary strengths can afford to do such research. So, instead of competing with them, quite vainly, we are giving the mantle to them. We will use their advances and build on them to bring out innovative solutions. As an example, we developed simulation model for a new RF wireless technology that will allow pagers, cell phones and other computer/communication units to exchange information (such as business cards) in the background. It could not be completed. But we now have the confidence that we can take on most recent developments and go further.

- **Build on the advances of others (Part II):** There is another reason for this as well. Christensen [Chri97] studied many high tech companies, both successful and unsuccessful, and developed a set of guidelines for capitalizing on the phenomenon of disruptive innovation. Such truly important, breakthrough innovations, or disruptive technologies, are initially rejected by mainstream customers because they cannot currently use them. This rejection can lead firms with strong customer focus to allow strategically important innovations to languish. An excessive customer focus prevents firms from creating new markets and finding new customers for the products of the future. As they unwittingly bypass opportunities, such firms can clear the way for more nimble, entrepreneurial companies to catch the next great wave of industry growth. Generally such disruptive technologies are technologically straightforward, consisting of off-the-shelf components put together in a product architecture that was often simpler than prior approaches. They offered less of what customers in established markets wanted and so could rarely be employed there. They offered a different package of attributes valued only in emerging markets remote from, and unimportant to, the mainstream.

- **Build a high-tech marketing strategy:** Moore in his best selling book, Crossing The Chasm [Moor91], shows that the Technology Adoption Life Cycle has a bell shape with clear cut transitions to different interest groups, starting from the few Innovators, to more in Early Adapters, to the peak of demand with Early Majority, and sustenance by Late Majority, and eventual buy-in of laggards and product demise. Moore shows that the typical MBA training on consumer marketing misses the point when it comes to technology marketing. Advertising and brand recognition of consumer marketing are no longer important. A relationship is and it can buffer the shock of change. What is interesting is that the Adoption Life Cycle is not continuous and has chasms or gaps in between to be overcome by the innovator. He recommends that one focus on one application, not all the possible applications of the technology, and move forward with speed and agility. Beyond that, referencing has a key role to play. This may apply both to our center and the business spin-offs. We do not yet know how this might affect our endeavors.

- **Separate the simple from the esoteric:** Teach/train all with the simple concept and tools. Reserve the esoteric methods and tools for the interested and premium priced programs. In the past, we have made the mistake of providing the courses with the best possible and industry compatible tools. This was tremendously demanding. While a few students appreciated and went on to good jobs with different high tech companies, others did not care and felt it was a waste of time. The department also did not help with the tool purchase and maintenance. So, the courses now on will use PC-based low cost tools, with the advanced tools taught only for interested students, at a price. This is the way most other universities manage, but we tried a different experiment, but were not able to convince the department to financially support this concept.

- **Encourage the faculty not to own the courses:** Develop the material so others can teach too. Bottom-line: we want to attract more students and provide them with uniform course material. Develop enough design examples and tutorials so the process becomes easy for others to teach the material. This will make it easy for the courses to be offered on a regular basis with a consistency that will attract more students.

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Appendix A: A Method for Commercializing New Technologies

We have used the following approach in a recent project on developing hands-on science projects for K-12. We discuss the method here. More details on its application to the specific project may be found at www.cvsi.fau.edu.

We use a methodology developed by Jolly [Joll97] to delineate what already exists and what has been accomplished already, so it is clear what lies ahead. Dr. Jolly does this for technological commercialization and we will pursue the same approach for our projects. For the long-term sustenance of these concepts, we need to approach the issue as one of commercialization, to keep the cost down and encourage widespread ownership and usage.

The process of technology commercialization [Joll97] in successful companies does NOT follow the traditional linear view of innovation, which is given in the figure below: The successful strategy is rather a segmented, value build-up view of commercialization. We adapt the same here for successful introduction and adoption of our products in the school environment. The stages are as follows:

Conceptualization	Develop the dual (techno-market) insight
Incubation	Define success factors (address low cost, school need, & support to be provided)
Demonstration	Develop contextuality in products and processes (Evaluation phase)
Dissemination	Encourage adoption
Sustenance	"Commercialization" (provide low cost, technology and training support)

Though segmented, the stages require bridges to satisfy and mobilize stakeholders at each stage. Clearly, all this needs a multifunctional approach.

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Traditional Model ***A Model for Success***

Appendix B: Theory Of Constraints – A Scientific Framework for Optimizing Management Issues and Its Complementarity with other frameworks for management and Innovation.

TOC is a management science invented by Dr. E.M. Goldratt, a scientist, an author and an educator. He used scientific methods to create concepts in management, which have proven to be of great value to industry [McMu98, Smit00]. TOC makes explicit those highly effective intuitive management styles of the past. Making previously intuitive processes explicit puts them within reach of more people and teams. TOC aims to improve throughput, a global measure of an entity, rather than use cost factors to provide local optimization in the sub-entities [Smit00].

Any management decision can be posed as a conflict between two (mutually exclusive) methods to achieve a similar end objective. In an organization, there are always proponent of either of the options, and may work to disarm/ slow down the other side as a strategic measure. However, TOC allows one to break the constraint in a synergistic manner that tries to retain the good values of both the options. TOC, as a primary requisite, needs the buy-in of upper management to succeed. Many industrial giants, such as GM, Ford, TI, HP, and National Semiconductors, have incorporated TOC at one time or another into their management systems. TOC is a scientific method – and hence, McMullen calls it the "Physics of Performance Improvement" [McMu98]. We tend to focus below on issues in product development process needs to be optimized.

Briefly, in TOC, the process starts by defining the system and its goal. Then, Global measurements of the system's progress toward the goal are established. Necessary conditions for continued system operation are identified and supported with appropriate measurements. Local measurements that support the system-level global measurements

are created to guide the faculty members, the center, and other supporting sub-entities of the system. The TOC five-step focusing process is now begun. To do that, a current-reality tree is built to represent the current state of the system. The primary cause-and-effect relationships affecting the state and the performance of the system are discussed and made explicit. Constraints that are blocking the progress of the system toward its goal are identified. Then, underlying assumptions are exposed and used to break the conflict. A future-reality tree and a transition-tree are constructed to incorporate the new insight and implement the plans. The results are measured.

Goal of any entity such as ours is to primarily to provide appropriate services, but generate sufficient cash to achieve that goal year after year. While the discussion below is geared towards for-profits, the through put and the objectives could be adapted for the needs of a not-for-profit. We plan to do that in our next revision of this document. For now, the discussion below will be with regard to a for-profit entity, which needs to make money now and in the future.

The global measurement is organized around the concept of TVA (Through-put value added). TVA is sales less costs that vary entirely with volume of products and services sold. The usual management reports and performance measures, while designed to help the company make money, have precisely the opposite effect, since they optimize local performance, without any way to tie it to optimize at the global level. TOC has three fundamental measurements: Throughput, or TVA, is the rate at which the system generates money through sales; Inventory, I ; and Operational expense, OE. Local performance measures are clearly given lower importance as compared to global measurements. A goal of the management may get attached to it as a necessary condition (such as, environmental and marketplace behavior) by stake holders. Any management improvement process should address the following three questions: What to change: What to change to; and How to cause the change. The first step would be to identify the high-leverage and high-impact projects.

Use of the five-step TOC focusing process and the TOC logic-tree processes literally forces the management teams to home in on solutions with huge bottom-line impact. The five step process is as follows: Identify the system's constraints; Decide how to exploit the constraints; Subordinate everything else to the above decisions; Elevate the constraints; and Return to the identification process and ensure that previous decisions are not constraints. Many improvement situations are either dominated by physical constraints, or are best approached via consideration of physical constraints. This may require drum-buffer-rope scheduling, to uncover large amounts of hidden production capacity in one's factories. Each time the primary constraint is identified and exploited, throughput is increased and non-value added activity is removed.

Current-reality logic trees (CRT) are used to characterize the combination of factors that are contributing to non-value-added constraining activity. Evaporating-cloud logic trees (ECT) and future-reality logic trees (FRT) are used to formulate and evaluate combinations of changes to the several policies and procedures that constitute a complete and sound change. FRT is the strategy, the vision, or the mission for the organization.

Prerequisite logic trees (PRT) are used to break large parts of the solution into smaller and more manageable components. Transition Trees (TT) are used in three ways: To document selected existing processes; To plan and accomplish one-time change; and To design and document the new recurring processes. Benefits of the Logic-Tree Thinking Processes are many. In addition to providing an explicit way to rationalize and evolve optimal solutions, it also helps the organizations become learning organizations, systematically evaluating other best practices against their own and inventing their own best practices. It also helps capture and document the learning organization's continually evolving know-how.

TOC thinking processes are not the only thinking processes ever invented. They may be, however, the single most simple, practical, and yet still most comprehensive general-purpose management thinking processes ever invented. There are a few other popular processes that came before TOC. Here we will mention only three. Total Quality Measurement (TQM) offers a variety of thinking tools, such as the fishbone diagram, quality-function-deployment (QFD) matrices, the five whys, and root-cause analysis [LeCo99]. McMullen [McMu98] indicates that TOC is clearly superior since it can be used virtually anywhere and offers significant advantages in terms of rigor, speed, clarity, integration, and communication support. Peter Senge's Fifth discipline approach articulates many cause-and –effect relationships in systems [SeKl94]. TOC can be used effectively with it. TRIZ is a structured approach to invention [Shul99]. TOC and TRIZ accomplish different things and are complementary. TOC can be used to sort out initial specifications for what should be invented, and TRIZ can then be used for the actual invention.

Appendix C: The Centerless Corporation [PaVi99]: A New Model for Transforming Your Organization for Growth and Prosperity:

The authors, senior managers and partners with Booz. Allen & Hamilton, a global technology and management consulting company , undertook an year long study of their client's business practices, good and bad. The study, initially focused on the role of the corporate center, soon had to be broadened in scope to include the other elements – its business units, governance, and services. The authors wished to resolve the fundamental issue for companies in 1990s: How to continue to grow and globalize? Many large companies have struggled through repeated reengineerings and downsizings, as a response to this. The corporate center has been the hardest hit. While everyone agrees that complexity is really the critical factor, and that the old command-and-control type of organization is no longer viable, the prescription for cure has been less obvious than ever before. Many leading management experts have advocated shedding businesses to focus. However, the limiting factor for growth and globalization is not complexity, but the tools businesses have to deal with it. Many corporations are over-structured, over-controlled and over-managed – but under-led by people at the top with regard to real leadership tasks that will guarantee success.

Their new model for success, the Centerless Corporation, exists to varying degrees in currently existing and successful global entities, but does not exist in its entirety at any corporation. Such a company would have a global core, but with most of the key missions of the organization distributed to the various business units and where unity comes from the vigor of people and the free flow of knowledge, not a burdensome central headquarters. Conceptually, this corporation would have **two concentric circles**. The **inner ring** would house the global core, business units, services and governances, while the **outer ring** would represent a free flowing glue that contains people, knowledge and coherence.

The Outer Ring: The old business model is structured around individual businesses. The new model would be built along three axes: **people, knowledge and coherence.**

People: The centralized leadership is no longer able to identify opportunities, create new products, and create synergy across the organization, while insulated from the entity. Committed and entrepreneurial workers are essential to ensure the competitive position of a company in this dynamic and rapidly changing society. Unfortunately, people represent a firm's most underutilized resource. But people are a significant investment in the future. The companies need to adopt a "new people partnership," a mutual commitment to establishing the environment for learning and ongoing employability as part of the overall package offered to the work force.

Knowledge: Knowledge enables growth and productivity, yet most organizations today are unable to harness that internal and external knowledge database. Knowledge, in this perspective, has the broadest connotation. It is not a mere accumulation of facts, but a collection of best practices internal and external to the entity, and customer intelligence. It is amassed from experience and is the primary building block of the company's capabilities. It is strategic and focused on enabling the firm to do something significantly better than others.

Coherence: This refers to the linkages that holds a company together and allows it to strive. They are the connectors among the many components of the firm, that allow the company to globalize, and yet work as one; management and organizational processes that enable the firm to function smoothly and profitably; and a host of other factors that help create value greater than the sum of the parts.

The Inner Ring: This new model needs a different style of leadership. The CEO is no longer there to manage the corporate activities, but to create the context for growth with a strong emphasis on the three enablers of growth. The context provides direction in terms of vision and culture, while the enablers actually make growth happen. Such refocusing leads to radically different roles for the four basic elements of the new model: **the global core, business units, services and governance.**

Global Core: The traditional corporate model has a linear chain of command and hub-and-spoke process to govern independent entities. That structure is hierarchical, with a large corporate and division staff, centralized functions and self-sufficient divisions. It is

multidimensional along major product lines. Extension of this corporate model to a global network conjures up the image of a loosely coupled helicopter – thousands of well-designed, highly machined parts flying in formation – hopefully.

The new corporation is flat, with a network of interdependent business units and strategic alliances managed by group executives. It is non-linear, with flows and alliances dynamically made for effectiveness. There would be different structures for different products and geographies. There is minimal staff at the corporate and group levels. Staff functions are placed in the business units, a services unit, or outsourced. This arrangement allows companies to compete with their full capabilities no matter where they are housed in the organization. Best practices and knowledge flow freely, finding their most productive use. The new model has no center in the traditional sense. The earlier center now is a global core, with the extended leadership team spread throughout the segments of the corporation to match the way the company works. The distributed core is also global since it is responsible for key missions across the entire corporation, imparting value to all of the other elements of the model. It is not a geographically placed center, since the global nature of business makes it imperative that companies perform many core activities close to where they are needed. Technology enables this. The core adds value where the business cannot. To a large extent, the new model is a mindset change as much as anything else. It does not look radically different, but the value comes from its radically different perspective, strategy, and action. But do note: Leading a distributed organization requires a different set of skills from leading a decentralized one.

Business Units: It is not the job of the global core alone to create value. The business units must also be able to contribute to each other's success, via best-practices exchange, knowledge sharing and capability transfers. The value created by the whole must greatly and measurably exceed the value created by the sum of the parts. When that fails to be the case, the individual business units are probably better off outside the firm.

To accrue some of this potential, business units will have to be managed differently. Greater interaction among units is a necessity. The boundaries of individual units must be more permeable and flexible. The challenge, however, is the individual unit oriented accountability and performance measures that rule the landscape. Self comment: The Theory of Constraints put forward by Dr. Goldratt attempts to resolve precisely this dilemma: how to focus the energies away from local optima, i.e., optimized performance of individual units, to global optima, which will view the organization as a whole and try to optimize the entire process [McMu98]. Unfortunately, though there are many stories of success, entire major organizations are yet to implement and move from local to more global performance measures. Our comments not withstanding, clearly the economic forces are already changing the thinking and rationale in this direction of global optimization and synergy.

Services Unit: Since many services are not key parts of the value-creation process, they can be done outside the firm. This may not be feasible. The solution is to create a market within the firm by establishing a separate unit to supply these services and force it to be

market-efficient. This is the concept of shared services. The service delivery can flow from several sources, but the corporate center should not be one of them.

Governance Unit: This takes on a much larger role than before. It has three types of governance: Of the entire corporation by the board of directors; Of the inter-corporate entities such as alliances and joint ventures; and Of intra-corporate entities such as shared services. A push for performance is creating more active boards with greater CEO accountability. The new board also needs to expand further by bringing insights on customers from a cross-section of industries and services; ensure that the company's key business capabilities are developed; and also as a control body, not merely advisory in capacity.

In summary, the challenges and complexities of today's global economy call for a new and radical change in perspective, from the old command-and-control process, to a strong focus on the ultimate value creators: people, knowledge and coherence. It must evolve toward a new business model that fosters the creation of value and insures that each component of the business contributes to system-wide value and synergy. Further, the firm is part of a bigger picture and trends and responsibilities in this bigger picture should not be ignored. Such changes are imperative. Absence of such initiatives will lead to smaller and weaker entities in the ever vain attempt to address the complexities of size and diversity.