Leadership Driven Innovation: The Role of the Engineer in Our Future

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Abstract

The proliferation of new technologies, particularly those identified as advanced and/or disruptive, rely on the development of two individual but highly interrelated competencies, leadership and innovation. These two are the basis for the successful development of most of the major technologies in production, today. At their best they are also the genesis for most of the large commercial and industrial organizations currently operating in the global marketplace. More importantly, it is the state of health of these two competencies that often determines the longevity and profitability of these organizations. This paper tracks a hypothetical progression from inception to long-term solvency for what can be idealized as a maturation process of a new company/technology. While this study is directed to represent most any type of new products and services, it is particularly well suited to advanced, and possibly disruptive, technologies and those organizations seeking and dealing in products for accelerating markets.

Keywords: New Technology Development, Leadership, Innovation, Disruptive Technologies

1 INTRODUCTION

There is a lot of rhetoric posited on the role of innovation in the progress and success of a new opportunity; be it a new technology, product, process, or service. The author's will attempt to illustrate a progression of activities, or states, whereby any of these could become successful and hopefully have a long, profitable life. What is apparent, to the authors, is that the novelty, uniqueness, or responsiveness to an identified need and its solution will not necessarily spell long-term success. A critical element to the mix will require the addition of strong, capable leadership. Leadership that understands and embraces innovation and the innovative spirit.

For most of the needs of modern society, the solutions, and the resulting products and services, will come from the technical arena created and nurtured by the people who generate them, thus the title of this paper. It is with the technically inclined that a significant number of the technological successes become manifest. It is to these individuals and their skills, motivation, and attributes that most long-term technological successes are attributed.

This paper will first define the terms and provide a hypothetical scenario for the growth of an organized effort or enterprise. It will also lead the reader through what it takes to bring a technology to market and, more importantly, what it takes to continue to support and sustain that growth. It will then lay out a timeline for the representative, but generalized, lifecycle for a new concept, technology, service, etc. along with the associated profits and losses, and risks and rewards.

Finally, it will differentiate between the types of technologies and the maturation processes normally associated with a successful enterprise. All of this will be covered in a generalized scenario where the timeline and the fiscal values would be scaled to fit most any type of enterprise. First the definitions, then the organizational maturation process followed by a challenge to the reader.

2 DEFINITIONS

This paper will use standard word definitions easily obtained through most any textbook or online. It is not a specific definition that was selected but, instead, ones that hopefully will easily resonant with the reader. While the specifics could be argued, the general theme serves to help define and highlight the focus of this paper.

2.1 Leadership

In its essence, leadership in an organizational role involves four main items: [1], [2]

- First, a clear vision must be established.
- Second, that vision must be shared with others so that they will follow willingly.
- Third, the information, knowledge and methods to realize that vision must be provided.
- Finally, leadership must coordinate and balance the conflicting issues of all members or stakeholders.

A leader should have their vision defined and clear to their constituencies early in the program, if not on day one. Leaders often come to the forefront during a crisis [1]. They are able to think and act quickly in creative ways to a variety of situations. They thrive on change and don't mind crisis. True leaders have no problem with crisis, while managers often do. Managers want things to stay the way they are or if they are to change, they want that change to occur in an orderly fashion. Leaders recognize that their role, plus the environment they work in, is dynamic and often volatile. [3]

Unlike management, leadership flows from the core of a personality and cannot be entirely taught [1]. It may be career acquired, but the skill set and attributes are inherent to the individual. It may also be learned or enhanced through coaching or mentoring but most likely it comes from the experiences that resulted from the individual's initiative [1]. The engineering skill set can also contribute to the core elements and values of that leadership make-up.

In other words, if you are a born leader then all of your experiences will build those qualities, most likely because you seek them out. If the makings of the leadership traits are there, then the process will happen, albeit most likely at a faster rate, if the opportunity is ripe and recognition is given to that growth by everyone in the environment.

2.2 Innovation

There are three definitions for innovation that will be used in this treatise.

> First: Innovation involves the deliberate application of information, imagination, and initiative in deriving greater or different value from resources. It encompasses all processes by which new ideas are generated and converted into useful products. [1]
>
> Second: The term innovation means a new way of doing something. It may refer to incremental, radical, or revolutionary changes in thinking, products, processes, or organizations. [4]

These are both very important definitions. Most people in an organization want innovation and will build their entire organization around the concept. They strive for it and try to reward it, but in fact, they often cannot even define what it is and, more often than not, let it pass them by for lack of vision and understanding. [2]

Arguably, innovation normally occurs "outside of the box." Truly innovative companies and their design and decision-making teams are often radical in their make-up. They have people with disparate personalities and skill-sets who work for and often around each other. Their innovators, at all levels, are often regarded as visionary trouble-makers, with unbelievably creative attributes who take calculated risks every day, often because they don't realize or even understand risk.

In addition, the third definition, business innovation, furthers this concept.

> In business, innovation results often from the application of a scientific or technical idea in decreasing the gap between the needs or expectations of the customer and the performance of a firm's products [1].

The key words in this definition are scientific or technical idea. It is normally a technology that reaches out to make a change, especially for the current state of our society.

3 INNOVATION/INVENTION TYPES

The terms innovation and invention are defined differently. A distinction is typically made between invention, an idea made manifest, and innovation, ideas applied successfully [4]. Everyone can invent, but few can innovate. An innovative idea is one that is carried all the way through to a product or a solution. It takes a very powerful, directed organization to take a product all the way to customer acceptance. Another way to define invention is the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out in practice. [4]

Since new ideas are a "dime-a-dozen", the individual, or organization, that can make ideas manifest are the innovative leaders. Innovation leading to increased productivity is the fundamental source of increasing wealth in an economy [4]. It is what innovation does to your economy and how you use it to plan for your future state that creates your ultimate, long-term success.

There are two primary types of innovation: revolutionary and evolutionary (see FIGURE 1). Revolutionary innovations are the breakthroughs, or disruptive technologies, often called gamechangers. [5] They are key for the success of any innovation-based organization where the goal is to be number one or to increase the market share by multiples. It is particularly true for the start-ups based on a new product or solution.

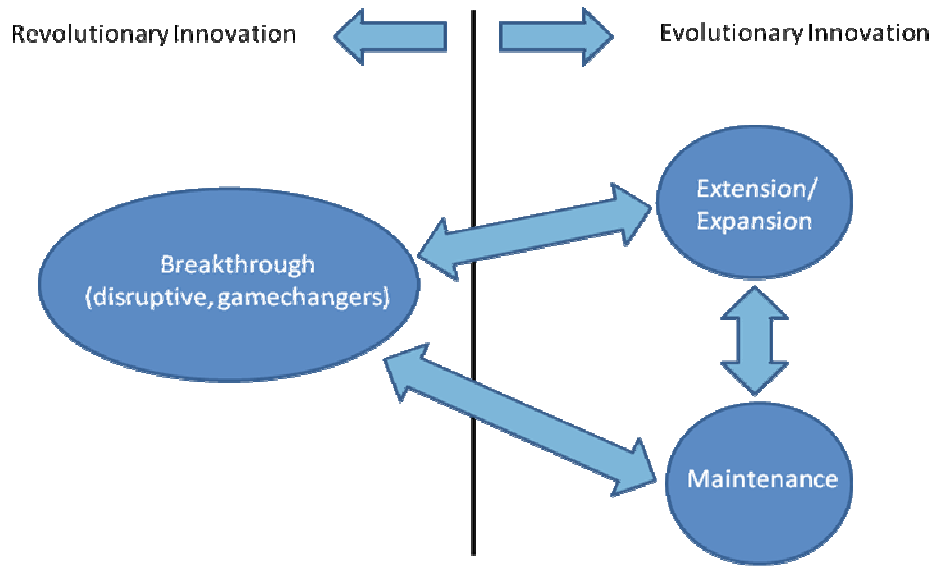

FIGURE 1: Innovation Types

Aggressive organizations want to have a gamechanger and look for and try to cultivate them. Sometimes though, the very organization that was created to encourage them gets in the way of their development due to a lack of strong and visionary leadership. [5]

The other part of the equation is evolutionary innovation. These are the extensions or expansions of current product lines, processes, or services. An example of this type of innovation would include product enhancement, or streamlining of a product line, creating a new cost structure, or cultivating a new customer base.

4 NEW TECHNOLOGY DEVELOPMENT

From the definitions provided, consider a hypothetical timeline for the lifecycle of a generalized, or generic, product or technology contrasted financially, noting that this exercise could also be applied to services or processes. The shape of this curve, FIGURE 2, could be applied to any product line or technology. While it will vary from one example to the next, if the time scale and magnitude differences are allowed for then the plateaus and slope variances can be identified against almost every product line or technology that has ever been created, at least during the modern technology age.

Conception and developmental cost projections are both steep, however when you get to initial production costs, the curve gets even steeper. Then the product goes out to the market and, if there is customer acceptance, the cumulative costs rate will start to decrease due to revenue being applied. After the customer starts to accept the product, the next step will be to create expansion and increase capacity, or possibly create other versions of this product for other sectors or markets.

At some point in time, this product or service will become mature which is when the cumulative cost rate starts to level off. By its nature, this curve will never go flat, but the rate of increase should flatten significantly.

FIGURE 3 reflects the cumulative revenue for a new product or technology. At the beginning of this curve, the cumulative revenue starts, and maintains, a zero growth rate until the initial customer production run. As soon as the consumer accepts the product or service, there is an increase in revenue and then at some time the beginnings of profit. The time line eventually

reaches the capacity expansion/extension region, where the slope increases significantly. At some point, the product or service will mature. As it matures, the market becomes saturated and effectively the product or service maintenance phase begins.

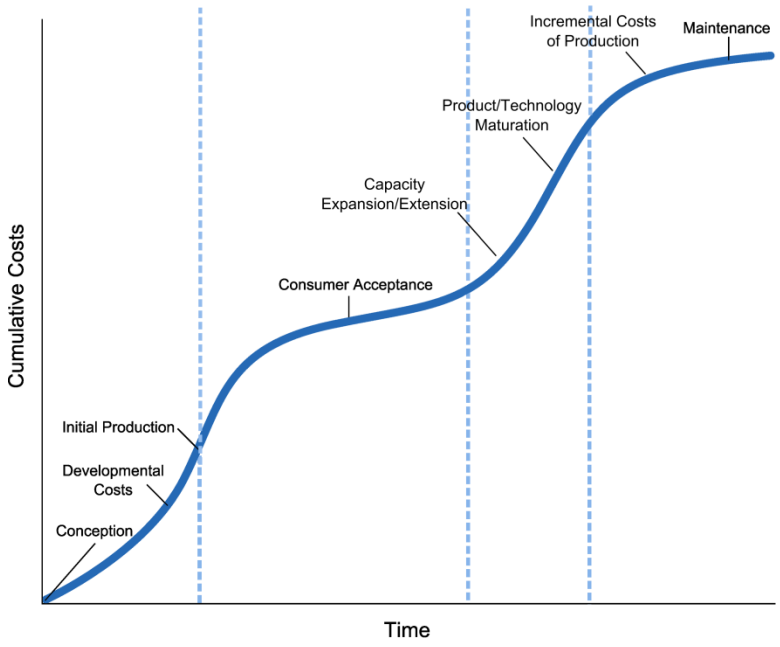

FIGURE 2 : New Product/Technology Development Cost

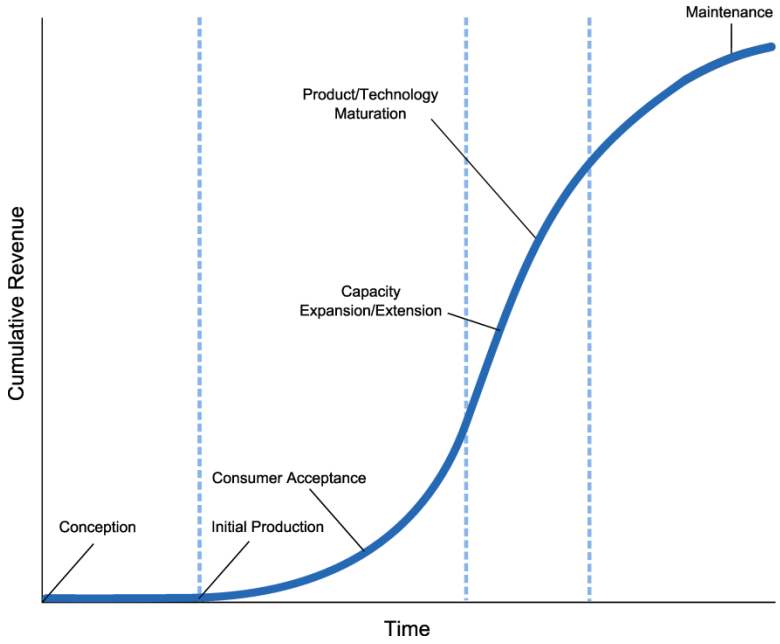

FIGURE 3: New Product/Technology Development Revenue

The last figure in this section is for cumulative profit/loss for a new product/technology development, FIGURE 4. At conception, significant resources are expended on a new product or technology so initially, the cumulative profit/loss rate will be negative. This is likewise the same for

the initial production, consumer acceptance and capacity expansion/extension phases where all are part of the investment losses, while there may be an inflection in the rate in the positive direction. The time scale is different for every product and service but it normally starts off with the same trend. These investment losses can be quite substantial, often retarding the growth of a product, and possibly the enterprise, or causing the delay or outright termination of the project due to corporate indecision or financial instability.

After the expansion zone, profits will start to occur. It is hoped that the product lifecycle is sufficient such that the profit side will grow much larger than the investment losses, resulting in a successful investment and decision strategy.

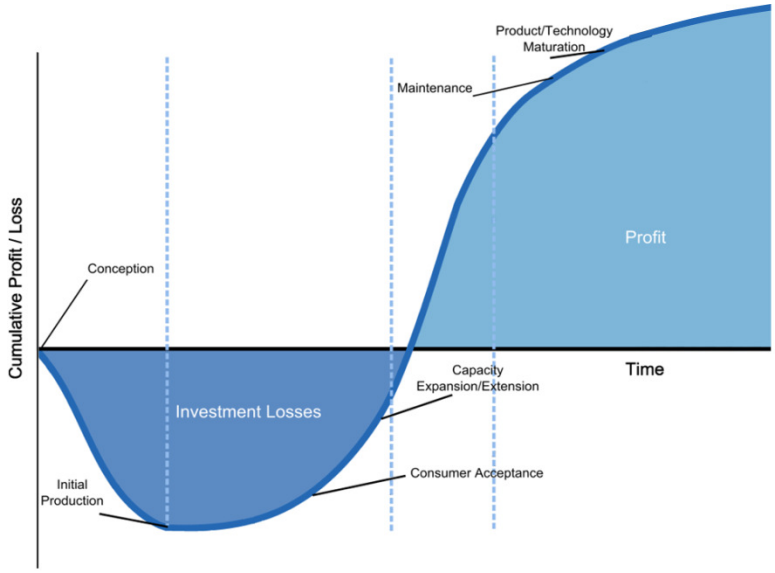

FIGURE 4: New Product/Technology Profit/Loss

5 INNOVATION RISK-TO-REVENUE COMPARISON

FIGURE 5 is a representation for the different levels of risk for the types of innovation involved. The two curves represent the rates and magnitudes of the differences between evolutionary and revolutionary innovations. Initially, they both start with a zero cumulative risk at conceptualization. The evolutionary innovation has a shallower risk threshold and eventually becomes horizontal as time is increased resulting from customer acceptance. Note however that the risks are much greater with the disruptive, game-changing technologies, referred to as revolutionary innovations. Some of this risk, or in this case cost, is associated with getting the technology refined and ready for production along with the associated needs for cost reductions required by the customer. The rest of the costs result from corporate management and production changes, disruptions in the day-to-day business focus, and of course, stakeholder acceptance.

There is also a significant level of risk in training the consumer and establishing a consumer base, not to mention getting the corporate leadership to initially embrace the new product in the first place, or after a lengthy and costly developmental start-up phase. The key is to get to the point where the consumer wants this product or technology and the enterprise can produce and maintain the production rate for the roll-out.

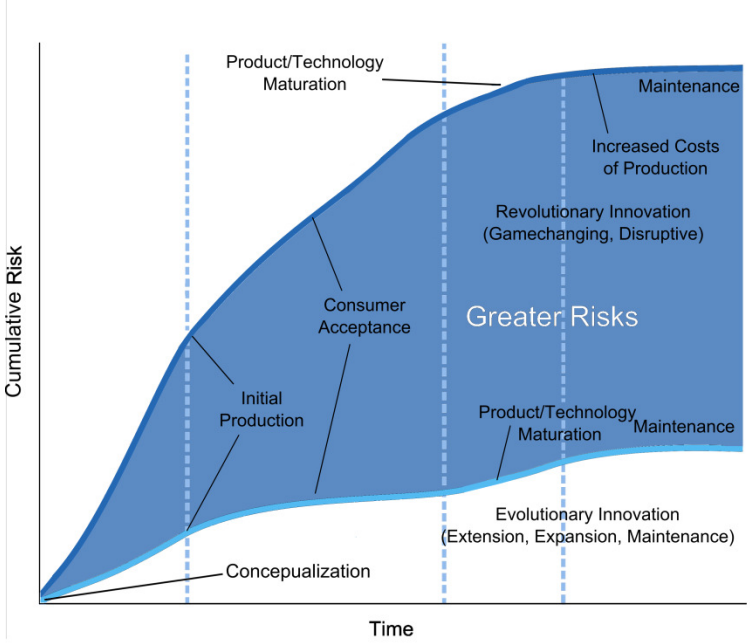

FIGURE 5: Innovation Risk Comparison

The final illustration in this section, FIGURE 6, is the innovation rewards comparison. Both curves are flat through conceptualization; however the revolutionary innovation stays horizontal a lot longer whereas the evolutionary innovation climbs much earlier, during the initial production phases. The revolutionary revenue curve can stay flat a lot longer than is depicted in this example and is often one of the reasons the technology is never considered, or abandoned early in the development phases.

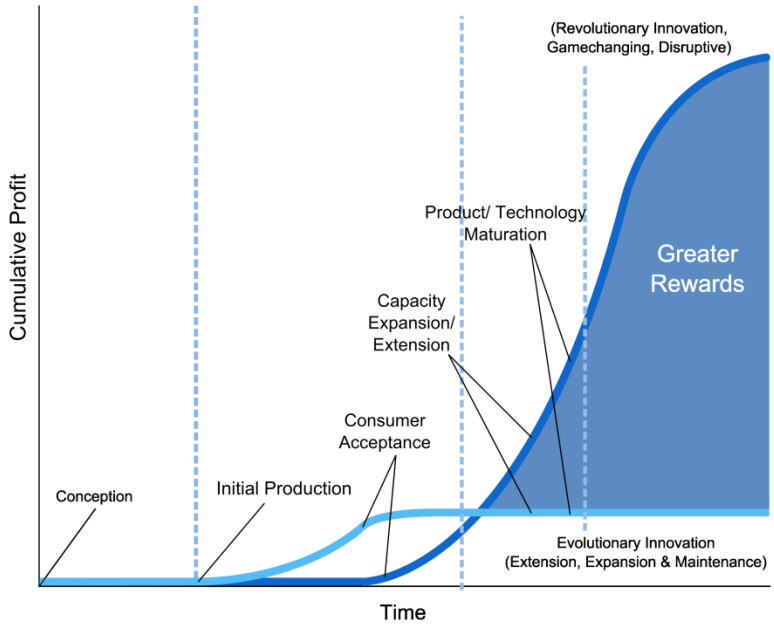

FIGURE 6: Innovation Rewards Comparison

Getting past the breakeven zone is critical for these technologies and the effective negotiation past this point as early as possible is often the key to the products or services continued enterprise and customer support. Clearly, getting past the high-risk zone results in multiples on the profit horizon, as compared to evolutionary improvements and, with hindsight, an easy justification for the original decision to take the greater risk.

It is the cost against potential margins that most organizations site as the value of an innovative technology, where often the same reasons are used as to why they are not considered, or overlooked, in the first place. This is where strong visionary leadership becomes essential.

6 BREAKTHROUGH TECHNOLOGY

It has been said that there has been a stagnation in the rate of technology development starting around the 1950's as viewed on a long term historical scale. The authors of this piece acknowledge that while we are most likely in line for a truly disruptive technology in the energy, transportation, communication or medical fields, there is still a steady introduction of evolutionary and some revolutionary technologies to sustain our imaginations and keep our marketplaces thriving. [6]

For thoroughness, consider FIGURE 7, a representation of the profit lifecycle of a breakthrough, or disruptive, technology. While this is slated to illustrate the more advanced and aggressive technologies, it is equally reflective of current developments and appropriate for this discussion since most of the current successful, long term, high technology companies started as disruptive ideas with strong, recognized (usually after-the-fact), leadership. These individuals were usually considered visionaries who were less than comfortable, or agreeable, with the then status quo. [6]

On the left, the curve starts at zero, then the consumer acceptance phase starts along with the market expansion/extension to establish the profit profile (difference between revenue and the costs). The market then starts to saturate and the technology matures. The line then becomes more horizontal where a somewhat constant profit line is maintained until competition is introduced. This could be a result of patent life expiration, loss of the founding leadership, foreign competition, etc. where the customer base starts to get eroded. Note that with competition or loss of intellectual property protection, the next step taken is to improve the economies of production which can extend the profit line. Sometimes these improvements can even cause a positive rate change in the profit line. Remember this curve is not particularly representative of any one technology, but is more intended to be a generalization of potential events.

Erosion of the customer base, production refinement/maintenance, and competition continues until the technology matures. The profits are normally at their lowest. All of the money was made in the first third to half of the time interval. At this point, the company is faced with the legacy burdens of maturing retirement packages, production line ageing and growing global competitiveness. Unless there is a further breakthrough or a significant redirection from the leadership, the company will end up making products for pennies on the dollar and the profit could have significantly decreased by orders of magnitude from the peak.

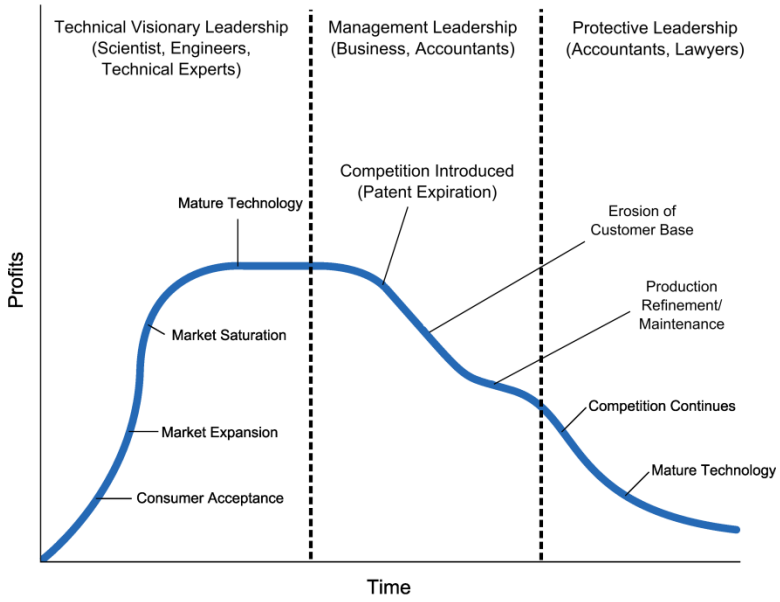

FIGURE 7: Breakthrough Technology Maturation Process

In general, for a breakthrough technology, the consequences are that it completely disrupts the status quo, displaces the work force, can cause economic upheaval and require that a new skill set be learned by everybody. If you are the second generation in that effort, it looks exciting. If you are the first generation, it can be intimidating and threatening. Another consequence of a breakthrough technology is the polarization of management and staff. You really need to have strong leadership to survive the initial birthing pains of these types of efforts.

Additionally, there could be the potential destruction, or at least delay, of share-holder value. If you create a new product and it knocks out your current product line, then your stock holders may not be content. Lastly, as soon as you create a breakthrough, everyone is going to want to make improvements or get caught up in the changes for change sake that occurs when progress and especially profits begin to swing to the positive. Again, this is another essential justification for strong leadership.

The last figure also speaks to a seemingly prevalent historical outcome. Most of the breakthrough technologies that have resulted in the development of market shifting enterprises have started in the minds and on the books of visionary leaders who were either technically literate or knew enough to team up with the same. These scientists, engineers, or technical experts formed and contributed initial intelligence as well as financial and sweat equity revenue to make their vision move forward. It was with them that the success, and often failure, resided. It was also with their beliefs that the course was drawn, based on their vision of what “will be” as contrasted to most individuals’ “might be”. It is with them and their foresight into training the future leadership of the organization that often is critical to the longevity of the enterprise. Even with their strong leadership their careers are often short in comparison to the life of a successful company and it is what happens after they leave, are ousted, or retire that makes or breaks the company.

Figure 7 also maps the types of leadership that can occur as a revolutionary enterprise matures. The technically competent, or well supported, leader helps bring the technology into being and then helps mature that technology through the various product stages. With the help of effective and strong management that product line and corporate financial base is strengthened sometimes at the expense of further visionary growth. Exploration of the technology becomes the driving force, as it should be, especially with the expected competition waiting around the corner.

Clearly, from some people's perspective, the next evolutionary step in the business is going to require strong management made up of business people and accountants to manage the resources, grow the product lines and ensure stakeholder value. Unlike the initial creators, their vision can often be limited to quarterly returns and maintenance of the core technologies and organizational framework. Eventually, this management style will start to feel the effects of competition, loss of intellectual property or governmental involvement and either start the dissolution of the enterprises or break out into another opportunity using the resources that have been built over the years to reinvest and reinvent the enterprise. If the correct visionary, often technical leadership is found, this can be extremely successful since some of the pains of an initial start-up can be reduced or eliminated.

If this doesn't happen, or is unsuccessful, then the third phase of the life cycle will most likely occur, protection leaders. This usually results in leadership centered around accountants and sometimes lawyers whose job it is to protect the share-holder value and maintain the operational integrity of the core enterprise, including the selling off or dissolution of assets often essential to the development of further visionary accomplishments, i.e. shutting down or limiting research and development centers or activities, reducing scientific and engineering manpower, etc.

The scenario above is not a required outcome but it is one that can be seen in numerous larger enterprises. There might be a corollary with the basic life cycle where there is a process of youthful vigor and vision, developing into a more mature security and growth phase and finally in a restructuring of priorities resulting from a loss of energy, will and an unwillingness to risk diminishing security. Whether art imitates life or the reverse it is clear that those companies that are long-term successful are also the ones that are "reborn", if you would, and are constantly trying to remake themselves as youthful, vibrant visionary entities. Most of these have learned that strong leadership with an eye to innovation is the key to their longevity. It is with these efforts that we find a healthy respect for the technically gifted and where if that talent has leadership skills they are encouraged to grow and help drive the effort. It is in this role that the engineer can be most effective no mater our overall competency to manage a business, because some of the required leadership skill set was cultivated with the educational and training process. Good managers are being produced in record numbers. The technically competent visionary leader is a little harder to locate and cultivate, thus the next section of this paper.

7 INNOVATION LEADERSHIP

"Strong leadership is a prerequisite for success at innovation". The characteristics that distinguish the best innovation leaders are the following [7]:

- The ability to tolerate ambiguity,
- The ability to assess and be comfortable with risk,
- The ability to balance passion and objectivity,
- The ability to change, and
- The ability to command respect, even from those who are skeptical.

These characteristics are the key. The best leaders need to maintain respect. They can't be right all the time, but hopefully they are not wrong too often. "Innovation requires and flourishes under strong leadership. The most innovative companies have a leader who wants to make a difference and leave a legacy of innovation". [7]

Very strong, positive leaders, while concerned, are not driven or constrained by next quarter's profits. They want to focus time and effort to getting the job done with the support and efforts of their constituencies. When they leave, they want the company to be in better shape than when they were hired and they want it to stay that way. When great leaders commit themselves to something, they want to know that it is something of value.

It is unclear where good or great leadership crosses the line with good or great management. It is most likely rare that you get a package where a person is great in both areas. It is also very

clear that just being a visionary innovator, or worse an inventor, is not enough to spell long-term success. It is normally the strong leader with an innovative sense to recognize the essential elements of an innovative technology, or better yet a potential breakthrough, that will provide the needed strategy and start-up energy. The best match might be a technically competent engineer or scientist who has innovative visions of the future combined with a strong leadership skill-set. [8] For those few individuals, understanding the essential elements to innovation is paramount, albeit they tend to be somewhat annoying to the rest of us who cannot see their vision.

8 KEYS TO INNOVATIVE THINKING

According to HR Magazine Columnist, John Graham, there are seven keys to innovative thinking [9].

1. Keep pushing the envelope
2. Think about the unthinkable
3. Be a confirmed contrarian
4. Become a creative doubter
5. Be daring
6. Ignore the detractors
7. Speak up

It is these key attributes, and many other forms of the same, that distinguish truly innovative thinking and activities. This combined with the proper leadership, while not guaranteeing success, does place an organization in the same ranks of those that have, and for the correct reasons.

9 CONCLUSION/LEADERSHIP CHALLENGE

This paper has attempted to look at the process that an organization takes to start and then arrive at a profitable, mature enterprise. Clearly this effort, at best, only generalizes and outlines the areas and scope of the effort. What the authors' want the reader to take away from this exercise is the need and value of having strong leadership and an innovation-based culture. Whether the innovation is evolutionary or has the potential for a breakthrough the process is still delicate and, at best, risky.

Knowing this up front and factoring in the need for planned leadership is the key to a successful future. Behind all of this are the technical people, the scientists and engineers, and the craftsman and technicians, who make it all work and who are, as often as not, the initial creators of innovation and the leadership that starts the new enterprise. Therefore, this piece will end with the following challenge pointed to the engineer and leader in all of us:

- Engineers must strive to become the agents for change: adaptive, supportive, and disruptive.
- Engineers must view innovation with a passion to be used as a tool to set policy for technological, cultural, and societal change.
- Engineers in positions of leadership need to promote an innovation culture, and seek support for the same.

10 REFERENCES

[1] (2009). Retrieved March 25, 2009, from Business Dictionary: http://www.businessdictionary.com/definition/innovation.html

[2] Collins, J. C., & Porras, J. I. (1994). *Built to Last: Successful Habits of Visonary Companies.* New York: HarperCollins Publishers Inc.

[3] Berkun, S. (2007). *The Myths of Innovation.* Canada: O'Reilly Media, Inc.

[4] McKeown, M. (2008). *The Truth About Innovation.* Pearson/Financial Times.

[5] Li, C. (2010). *Open Leadership: How Social Technology Can Transform the Way You Lead.* San Francisco: Jossey-Bass.

[6] Christensen, C. M. (1997). *The Innovator's Dilemma: The Revolutionary Book that Will Change the Way You Do Business.* New York: HarperCollins Publisher's Inc.

[7] The Boston Consulting Group. (2008). *Innovation 2008.*

[8] Florman, S. C. (1996). *The Introspective Engineer.* New York: St. Martin's Press.

[9] Graham, J. (1994, June). *The Truth About Innovation*. Retrieved March 25, 2009, from The Financial Times: http://findarticles.com/p/articles/mi_m3495/is_n6_v39/ai_16097384