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Engineering — What You Don't Necessarily Learn in School

WEB EXCLUSIVE

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As young engineers progress in their careers, they begin to understand that there is far more to being an outstanding engineer than they might have thought during their days as an undergraduate. In fact, some of the things they need to know weren't necessarily learned in school. And this is understandable, given the relatively short time spent in school and the significant differences between the missions of academe and industry/government.

This paper focuses on twelve vital aspects in engineering that are usually learned after graduation but can make the difference between success and failure in one's engineering career. To succeed, engineers must: learn to be business oriented; expect tough, multi-disciplinary problems; learn to work and network in the new multi-cultural and multi-national environment; understand the differences between academe and industry; learn to differentiate all over again; understand the values and culture of their particular company or organization; be open to ideas from everywhere; have unyielding integrity; make their manager a success; support their university and technical society; have fun; and most importantly, manage their careers. Each of these aspects is discussed in detail.

In my particular job, I have the pleasure of interacting both with a large number of young engineers just beginning their careers at GE and with a lot of students at universities who are working towards their engineering degree. These are exciting times for them, and rightly so. I try to assure them that they have chosen a career path that can lead to great satisfaction.

Quite naturally, this interaction often spawns discussion about careers and the question invariably arises, "How can I succeed in engineering?". I wish I could give them a mathematical equation whose solution would guarantee their success. But I know of no such equation. I have, however, gained some insights about succeeding in engineering that my fellow engineers and I have learned over the years. I offer twelve insights, explained in detail in this paper, and hope they will be beneficial in helping young engineers focus and manage their careers.

These insights are not just 'one manager's opinion'. As expressed in the Acknowledgements, I had this paper critiqued by many of my colleagues in industry, academe and government, including chief technologists and senior engineers at the three major aeroengine companies, GE, Rolls Royce and Pratt and Whitney. There was overwhelming support from industry for the validity of these twelve insights.

1.0 LEARN TO BE BUSINESS ORIENTED

Being business oriented does not mean going out and getting an MBA degree. It does mean developing a mindset that understands some of the things that make businesses tick and then operating within that framework or new mindset. It means understanding the economics of your particular business and how this affects engineering decisions. It must quickly be pointed out that engineering professors are usually well tuned to the many business aspects of running their research programs, their department or a university; however, most undergraduate students are isolated from the business aspects of academe.

Engineers will need to:

1.1 Understand the "Cost of Doing Business."
That is, understand the total costs involved for your company or organization to produce their product. This basic concept is relevant for any engineering discipline, but the following example will illustrate the point. The gas turbine business, which those in IGTI have chosen as a career, is expensive to operate. Our product is very complex and expensive to develop. It can cost well over a billion dollars to bring a new, turbofan aircraft engine to the point of engine certification for airline use. Derivative engines can cost 300 to 400 million dollars to develop.

In addition, engineering labor is very expensive to a company. Typically it costs over $200,000 a year to employee a U.S. engineer because overhead and benefits cost a lot more than your salary. Downsizing five engineers can save over a million dollars. These facts, combined with the fact that the materials required are often exotic and the product is difficult to manufacture, makes the selling price high. In addition, the market for our product is limited and extremely competitive.

Imagine going to an investor and asking for a billion dollars to develop such a product with the risks involved. But these are the realities of the gas turbine profession. Consequently as you progress in your career, these aspects will likely become increasingly more important in your decision making process.

And these kinds of realities, in varying form, exist in almost all other industries. So we are not alone.

1.2 Realize that Today's Marketplace is Global.
Ready or not, you are part of the new global business world. The "Buy American" or "Buy European" mentality isn't reality today. Increasingly larger portions of our products are designed, manufactured, tested, serviced, etc. outside of our country. We must do this in order to reduce costs or to sell our engines, power turbines, automobiles, etc. in other countries. They want a piece of the pie too. Therefore engineers must have global brains and must think and act multi-culturally to build diverse and global teams. Those countries outside the traditional 'industrialized block' are becoming increasing more important and competitive.

Much to their credit, universities have long been on the forefront of global action in diversifying their student population and faculty. Your exposure to other cultures and interaction with diverse students is an excellent experience for entering the marketplace.

Yet it is important to keep in mind that this is just the beginning. Now you will actually have to work side-by-side or across the ocean with diverse engineers.

Globalization is a major theme for large companies, not only for marketing and selling products but also for securing engineering and other labor. Modern communication and computing capability is moving the workforce to be more internationally seamless. Your local call to a "help-line" may be answered on the other side of the earth. And engineering work in your company may be done there too.

Remember the adage, "Yesterday's competitive 'enemies' may become tomorrow's 'partners'". This adage is now multinational.

1.3 Understand the Relevance of Profit.
If you work for a company, it is important to realize that "Your Company is in business to make a profit and will eventually go out of business if it doesn't, at which point you will not have a job". The last phrase in that sentence is critical to your well being, regardless of your profession.

The shareholders investing in your company want to earn dividends and see your company grow. Profits are a sign of the health of your company. Therefore, you must realize that your company is going to adjust manpower and budget to meet profit and other business goals. So even if it does not go out of business, your company may downsize — and the downsized person may be you. But the good news is that you can take steps like those outlined in this paper to make yourself more valuable, thus minimizing your risk.

You are going to have to learn to work within a financial budget and time schedule. Typically these are imposed on young engineers, but as you progress, you will be responsible for setting and managing them. As you help your organization prosper, you in turn will prosper.

1.4 Learn to Diagnose and Manage Marketplace Change.
Modern business leaders like Jack Welch, past CEO of GE (Welch, J. F.), emphasize the critical importance of managing change in order for the business to survive and grow. This is particularly important for the aerospace and gas turbine industries, which have well documented business cycles that ebb and flow with airline passenger traffic, worldwide economic conditions, world crisis events, military procurement plans, etc.

Business leaders and engineers alike must diagnose and manage their business and their careers through this change. While specific catastrophic events such as September 11 or meltdowns like Enron are unpredictable, they must still be managed. These two events have had a major impact on world economics.

Change occurs as fierce competitive pressures can force companies to restructure their way of doing business, reduce workforce significantly and reduce the cost of their products, which reduces revenues. Change occurs when companies lose market share. Change occurs when the business becomes more cost-driven than technology-driven. Change occurs when engineers need to resolve complex technical issues within a framework of new ways of doing business, perhaps with fewer resources or the need to use outsource help in foreign countries. Positive change occurs when your business thrives.

Significant personal change can occur if you are told that your services are no longer needed. As devastating as this can be and hopefully it will never happen to you, if it does, you must still manage it to succeed elsewhere.

I suggest that you read the short book "Who Moved My Cheese?" (*Johnson, S.*). You can read the whole book in one airline flight. In this book, "cheese" is a metaphor for what you want in life (career, organization, promotion, family, etc.) and the "maze" is where you have to look for what you want. Two sets of characters 'Hem and Haw' and 'Sniff and Scurry' have to deal with unexpected change as their cheese is moved into different parts of the maze. One set of characters fails and the other set succeeds. In your career, someone will invariably move your cheese. The question is, which set of characters will you emulate?

Regardless of the change, failure to recognize it and respond to it can injure or kill your company and/or your career.

1.5 Beware of Your Competition.
Competition in today's engine and powerplant market and in most other industries is absolutely fierce. And success can breed failure if complacency sets in. To quote Art Adamson (Adamson, A.), a retired senior manager, "Outside competition, in its eternal effort to succeed, wants to snatch your success, wealth, markets, and affirmation...". Art goes on to say, "Inside competition between you and your fellow workers for recognition, advancement, etc. must be handled more deftly and on a different level".

You are undoubtedly aware of competition. You've seen it in college entrance, in exams, in sports, etc. But regardless of the source, competition must be recognized and handled. Failure to respond can damage your company and/or your career.

1.6 Learn the Color of Money.
Although all of it spends, there are many types of money in an engineering environment and these types often cannot be interchanged or co-mingled. The term for these different types of money is 'color of money'. This is especially important in dealing with the government. I can't count the number of times I have heard the phrase "That's a color-of-money issue". Some various types of money and their explanation are shown in Table 1.

Table 1. Types (color) of Money

Type of Money	Explanation or Use
Investment	Capital improvements (buildings, equipment, etc.)
Expense	General and administrative, (overhead) travel and living, developing something you don't sell, marketing, training.
IR&D	Advance state of the art, advance technology.
Profit (DA)	What's left after expenditures.
Contract	What others outside give you to do work.

Temptations to abuse the color of money can come about as engineers try to complete projects within budget. For example, an engineer is managing a fixed-cost U.S. government contract that is about to overrun costs and at the same time is managing an IR&D project that is under-running costs. In order not to overrun budget, the manager could be tempted to direct employees to charge the IR&D account when they are doing the government contract work. This is illegal. Both managers and engineers must understand that penalties can be assessed for mixing types of money. These penalties can be in the form of fines, companies being barred from government contracts, employee discipline or dismissals. Whatever the temptation, don't do it either as a manager or as a subordinate.

2.0 EXPECT TOUGH MULTI-DISCIPLINARY PROBLEMS

2.1 Tough Problems.

The problems that you will face in your engineering career are tough and will be more multi-disciplinary than those you faced in college. This makes life exciting, challenging and rewarding. Understand that the word 'multi-disciplinary' is used in the broad sense. That is, one must draw simultaneously on many technical and non-technical disciplines, like aero, heat transfer, bearings, materials, purchasing, manufacturing, legal, etc. to solve the problem. It doesn't mean that I use calculus learned in class A to solve the dynamics problem in class B.

It is my experience that professors do a very good job in educating students; however, both must work within the constraints of course schedule and limited classroom time. This is challenging. Consequently, many of the homework problems are designed to be worked in a matter of hours or days and thus cannot contain much of the kind of simultaneous, multi-disciplinary thinking described above.

But our product is very complex, requiring engineering skills from many disciplines. Most of the time you cannot say, "this problem isn't in my field" because many design issues overlap technical disciplines and problems are often caused by a chain of events. Therefore it is in your best interest to broaden your technical understanding across engineering disciplines as much as you can. Learn the basics of relevant specialties other than your own.

Leading universities give you some experience in this area through co-op programs and multi-disciplinary design courses. Some of the topical areas I have seen include building a formula one racer, a sailplane, a Mar's rover, a satellite stability system, etc. These projects require the kind of thinking that will serve you well in industry. If you participated in such a design or co-op activity, you should congratulate yourself.

Most of the easy problems are solved, no matter what your specialty. Fortunately our business is filled with thousands of small ways to improve, which when taken together can produce significant advancements.

2.2 Learn When to Stop.

There comes a point when further design, further analysis and further research does not add to the value of the product and drives in unnecessary cost. So engineers must learn not to:

• Over-design things because cost, manufacturing complexity, etc. increase.

• Over-research things. Do we really need to know that answer? This is a particularly difficult concept for advanced-degree holders to grasp because they are trained in Ph.D. research techniques, which strive for complete understanding of underlying principles.

• Over-analyze things because that last 0.05 points in efficiency may not be real. This pathology is aided by modern computer capability.

So find out what constitutes "value" as defined by your customer and drive this into the product in a manner that stops at the appropriate point. This is often described as listening to the 'Voice of the Customer' (VOC) and finding what is 'Critical to Quality' (CTQ). You will do well to make VOC and CTQ's an important part of your engineering experience.

2.3 Learn from Discrepant Events.
A discrepant event is encountered when information received is different from that expected, previously experienced or thought to be true. Educators tell us that we learn more from encountering a discrepant event than we do from encountering an event that we expect to find. Discrepant events force us to re-evaluate, learn new facts, new concepts and new generalizations and perhaps even change. That unexpected result you encountered on test may not be bad data.

Gerhard Neumann, past president of GE Aircraft Engines, told the story about the first test of his invention, the variable stator concept for axial compressors in the 1950's. The test results showed such good performance improvement that his management didn't believe the data. This was a discrepant event for them. They directed him to completely tear down the engine, re-build it and re-test it. Upon retest, the improved performance held. Much was learned from this discrepant event. Variable stators are now part of modern engine design.

3.0 LEARN TO WORK AND NETWORK IN A NEW ENVIRONMENT
Many young engineers inherently understand the value of working but do not yet appreciate the significant value of networking, i.e., the supportive system of sharing appropriate information and services among individuals and groups having a common interest. It takes time and much effort to "connect" with the local, national and international players in your field, but it will reap rewards in the end. Networking can help as you seek to advance your career through job change or promotion, through technical society work, etc.

3.1 Work and Network in a New Time Scale.
Most students that I encounter work very hard; nonetheless, college time-scales enable the student to have a clean slate each semester or quarter. By the real and necessary constraints of the educational process, classroom undergraduate assignments are usually posed and solved in a few hours, not unlike the very compressed time scales of an exciting theater or TV drama. Homework problems assigned in one class are hardly ever worked in conjunction with those assigned in another class taken at the same time. Ph.D. thesis time scales, by their very nature, can be glacial compared to industry needs. It simply takes three to five years to properly train Ph.D.'s and have them demonstrate sound research techniques in original work. This is the way it is.

On the other hand, industry time scales are different. Projects are multi-disciplinary, take much longer than homework assignments and are very much more faster-paced than Ph.D. thesis projects. There is a constant attempt to shorten concept-to-market time and there is explicit regimentation to meet the work schedule.

3.2 Work and Network as a Team Player.
This section must be explained carefully. The critique given by a few university colleagues is that they do create a team atmosphere amongst their graduate students and faculty, one that promotes interactive discussion and help as students try to work out best solutions. This is good and certainly useful. But it is usually conducted amongst like-minded (same discipline) colleagues. Although I certainly include this as an important teaming effort, it is not the kind to which I am referring here.

I am talking about functioning in a team atmosphere whereby groups of engineers in varying technical disciplines come to the design table with different and often conflicting needs, wants and solutions. Such an atmosphere is both exciting and testy, but you must learn to function well in it. For example, the aero designer wants a certain complex airfoil shape and thinness, the mechanical counterpart wants a much thicker airfoil, the aeromechanical designer says the complex shape has resonant frequencies, the materials engineer wants a certain material, marketing says its too expensive, and manufacturing says pox on all of your houses because I can't manufacture that. How do you reach consensus?

At a university, a Ph.D. thesis must be the original work of an individual. Classroom assignments are most often structured so that you must work by yourself. There are, of course, some creative professors and departments that give very well-posed university team projects; however on most assignments, you must hand in your own solution. This is appropriate.

But in industry you can accomplish practically nothing by yourself. You will need to work in teams in as nearly a boundaryless (seamless) manner as possible. This is often difficult, but you must do it. The tendency to perceive other engineers and other organizational groups as the enemy must be resisted. Rarely will a company promote or honor an uncooperative, non-team player.

3.3 Work and Network with Good Communication Skills.

Like it or not, you will have to document your work in all kinds of reports, design books and memos. You will have to make oral presentations and discuss things with peers, managers and customers, etc. Become good at it. Classes in effective presentation and communication may help. If you aren't good at it, you can damage or impede your career.

Learn how to give a good "elevator speech". The idea is that you walk into an elevator and the VP of engineering or your general manager is there and asks you how your project is going. You have a few floors of travel to explain the value of your work. These folks don't have time to listen to details. Can you be concise, cut to the kernel of your work and give them a good impression in 60 seconds?

Sometimes attempts to communicate in a clear manner can be humorous. The following is a quote taken directly from the operations manual for pilots of a major non-US airline. "There appears to be some confusion over the new Pilot Role titles. This notice will hopefully clear up any misunderstandings... The Landing Pilot is the Non-Handling Pilot until the decision altitude call, when the Handling Non-Landing Pilot hands the handling to the Non-Handling Landing Pilot, unless the latter calls "go-around", in which case the Handling Non-Landing Pilot continues handling and the Non-Handling Landing Pilot continues non-handling until the next call of 'land' or 'go-around', as appropriate." What is that again?

3.4 Work and Network in the New Multi-Cultural and Multi-National Environment.

The engineering and business world is vastly different from what it was a generation or two ago, as discussed in Section 1.2. Business is much more multi-national. Engineering and high-tech jobs are increasingly going to offshore locations where labor rates are lower or where some favorable commercial benefit is obtained. This will require you to work with people of vastly different cultures, languages and ethnicities located in vastly different time zones. Some have proposed a 'work around the clock' culture, where work is passed from one time zone to another in a 24-hour continuous loop. But beware; this climate is an ideal breeding ground for Not Invented Here (NIH), discussed in Section 7.2.

4.0 UNDERSTAND THE DIFFERENCES BETWEEN ACADEME AND INDUSTRY

I must tread carefully here because this section can easily be misunderstood. The overwhelming consensus is that there are real differences between university and industry cultures and that these two cultures have drifted apart over the years. Working to reverse this drift in certain areas provides value.

4.1 Real Differences.

The university culture in which you are training or have recently left is quite different from the engineering, business or government culture you will likely enter. Understanding this difference is important because you will need to make an adjustment in mindset as you enter your engineering job. It is particularly relevant for Ph.D. graduates and some master degree graduates who have been trained to do research in an academic, scientific environment rather than an engineering environment.

A number of key differences between academe and industry are given in Table 2. It must be strongly emphasized that one column is not right and the other column wrong. They are different for valid reasons. They are also generalization, which means that there are exceptions. However, be informed of these general differences and be prepared to acclimate to them.

Table 2. Some Generalizations Showing Comparison of Academe and Industry

Academe	**Industry**
1. More individual oriented	1. More team oriented
2. Is it original work?	2. Can we leverage existing work?
3. Does it contribute to science?	3. Does it contribute to the business?
4. Will it make archival publication?	4. Will it make it into production?
5. Is it interesting to do?	5. Is it worthwhile financially?
6. Develop the equations, analysis, etc. from first principles	6. Fit a curve through the data and/or anchor the existing analysis
7. Is it original and complete from scientific (physics) perspective?	7. Is it institutionalized into the system from an engineering perspective?
8. Graduate when thesis finished	8. Meet schedule and budget
9. Publish, publish, publish	9. Customer, customer, customer
10. Sound scientific process	10. Design practices, templates
11. Non-profit institution	11. Profit institution
12. Solve roadblock issues as they occur	12. Identify and manage risks carefully up front with risk abatement plan and critical path scheduling
13. Professors (especially tenured) are independent	13. Formal management process up to shareholders

Engineering professors tend to conduct research in an individualistic (independent might be a better word) style. This does not mean that they don't consult with others or don't have group meetings with other faculty or students, etc. It does mean that they are generally free to work independently on those areas of technology that are of interest to them (and for which they can also get funding). They thrive on generating original, creative scientific work.

Likewise, while consulting with others and all that goes with it, graduate students must, in the end, conduct independent, original research. And they must defend their thesis alone. In addition, professors operate under a set of metrics for their promotion and peer evaluation that rewards research quality (e.g., number of archival publications in the prestigious journals of their field) and the amount of research money they bring in. They tend to train their graduate students to develop the equations and analyses from first principles. They are usually employed by a non-profit institution.

Achieving tenure provides the degree of independence they seek for unfettered research that contributes to science. At this level they have no manager. This is the educational environment in which you probably trained.

On the other hand, engineers and engineering managers tend to form teams and do their work in a team environment that will likely be very different from any academic team you may have encountered. They are not free to work on whatever problems interest them or advance science. They operate under a set of metrics for their promotion and managerial evaluation that rewards contributions to the business and engineering excellence which in turn enables the company to beat the competition, fix a field problem or gain increased market share. They concentrate on creative engineering design and analysis work that leverages design templates and existing work or anchors findings in existing analyses. Archival publications often mean very little. They are usually employed by a for-profit company and tend to be customer-focused. There is a well-established chain of management command up to the shareholders. This is the environment in which you will likely be working.

4.2 Science and the Art of Engineering.
Over the past four or five decades, engineering departments at U.S. universities and colleges have gradually become more science and physics oriented, more research oriented and less art-of-engineering oriented. Industry on the other hand is very engineering oriented and has become much more business oriented. To be successful, the engineer needs to combine all of the above to have both technical capability and business acumen, and these need to be properly balanced. But there is more.

Of course engineering is high tech, is based on the principles of physics and uses the complex math that you learned in school. But it is much more than that and you must absolutely grasp this "more-ness". As you progress through your career, you will need to learn what some call the 'art of engineering'; that is, the art or science of making practical application of the knowledge of pure science, physics and math to construct useful things like engines, airplanes, bridges, buildings, etc.

Generally, you learn the science and math of engineering in school, but you do not learn the "art" of engineering. This takes years of experience. Yet, as you transition from academe to the workplace, it is vital that you do learn it. If you have not gotten your hands on the product and interacted with it in some way, you likely have not "experienced" engineering.

4.3 Freedom to Publish vs. Protecting Proprietary Information and Intellectual Property.
This topic highlights a very important difference between academe and industry and gets to one of the core operational philosophies of the two institutions. Although intellectual property and its ownership is very important to both institutions, the timing and manner in which it is released to the public are often different.

A cornerstone of academe is 'unfettered research and open publication'. Most universities have the policy that their faculty are free to choose what research areas they want to pursue and free to publish their research findings (intellectual property) unfettered in the open literature. Some universities (and professors) hold this view more strongly than others, but the general idea is a common theme that is important to their success and prestige.

On the other hand, a cornerstone of industry is strict control over and protection of design procedures, research findings, etc., (commonly called intellectual property and proprietary information). This is vital to a company's competitiveness. Thus, unfettered and open publication of results in the university sense is significantly controlled. This situation can lead to frustration especially for those new graduates who are used to an open publication environment.

Nevertheless, engineers must understand that protecting intellectual property and proprietary information constitutes a sacred trust with their company. You will not be free to publish or release information without an internal review process that usually involves legal, patent, export control, marketing and engineering. In addition, you will be expected to sign proprietary information agreements and patent ownership agreements with your company as a condition of employment.

These very complex issues come into sharp focus when universities and industry want to do collaborative research under contract. There is no "one size fits all" solution. Although I know of no professor anywhere who will knowingly publish company proprietary information, the process of reaching compromise on intellectual property in legal contracts is often a challenge of major proportions.

5.0 LEARN TO DIFFERENTIATE ALL OVER AGAIN

5.1 Learn a New Kind of Differentiation.
You learned to differentiate in calculus. That is not what I am talking about here. What I am talking about is the kind of differentiation discussed in Welch (see References), Pages 157-162. In it he says, "In manufacturing, we try to stamp out variance. With people, variance is everything." Differentiating people and differentiating their leadership and the impact of their work in an organization isn't easy, but it is a vital thing to do.

It comes down to sorting out the top, the vital middle and the bottom tier players. Your managers are going to do this in some way or another, so why not give yourself "edge" by beating them to the game. Learn to recognize what differentiates you from the crowd and market it. What are your strong AND your weak attributes? Enhance the former and fix the latter. Apply this same kind of differentiation thinking to your company, your associates, the technical papers you review, etc.

5.2 Capture the Four E's.
Outstanding people, including engineers, possess at least four common traits, expressed as the Four E's (ibid., Page 158).

• Energy — They have high energy levels and enthusiasm for their work. They are dynamos who accomplish things.

• Energize — They have the ability to energize others around common goals. Their enthusiasm is contagious.

• Edge — They have discernable characteristics that separate them from others in measurable, favorable ways. They can make tough yes-and-no decisions.

• Execute — They consistently deliver on their promises. It isn't that they don't ever make mistakes or take risks, but overwhelmingly they deliver.

Conduct your career with the Four E's as a goal and you will reap a multitude of dividends.

6.0 UNDERSTAND THE VALUES, CODE OF CONDUCT AND CULTURE OF YOUR PARTICULAR COMPANY
What are the values and code of conduct that your particular company or organization promotes and lives by? Learn them and live by them (provided they are legal and moral, of course). For me personally, they are called "GE Values", and they are published, promoted and insisted upon by management. You will have "your company or organization values" and culture.

It is a great thing to have a benchmark and code of conduct like this against which you can measure your actions and the actions of others. Companies take these very seriously. They relate to honesty, trustworthiness, conflict resolution, fairness, safety, diversity, etc. If you can improve them, try to do so. If they need changing, be a catalyst for this change. If you just cannot fit into them, move on. Otherwise you may be "moved on" faster than you think.

7.0 BE OPEN TO IDEAS FROM EVERYWHERE

7.1 Attitude, Attitude, Attitude.
In real estate transactions, they say there are three important things people consider about buying a piece of property — location, location, location. In your engineering career, there are likewise three important things people will notice about you — attitude, attitude, attitude. Nourish a positive, can-do attitude. It is an important key to success. There are few things, aside from downright incompetence, that can hinder you as rapidly as a bad attitude.

7.2 No NIH Attitude.
The concept of not-invented-here (NIH) refers to the rejection or discrediting of ideas because they come from

sources outside the group. It is unfortunately more rampant than you might think and seems to be pathological with some people and organizations. You must overcome this mindset because an NIH attitude can kill you technically and cause ruin in your business and career. Other people and groups can have better ideas than you have, even if you are a manager.

You must learn to accept right ideas and reject wrong ones regardless of their source. And believe me, it is too easy to just reject a new idea because the person presenting it doesn't appear to you to have enough engineering experience or the idea came from another organization or company.

So persist with your ideas and be open to others. Invent something. Make something work. Be an "idea" person. But remember, Thomas Edison once said, "Invention is one-tenth inspiration and nine-tenth perspiration" (The Oxford Dictionary of Quotations).

7.3 History's Bold Forecasts.

History is full of detractors of new ideas. The following collection of bold forecasts about new ideas (Time Magazine) is amusing as well as educational.

- "This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us." Western Union internal memo, 1876.

- "Heavier-than-air flying machines are impossible" Lord Kelvin, president, Royal Society, 1895.

- "Everything that can be invented has been invented", Charles H. Duell, Commissioner, US Office of Patents, 1899.

- "Airplanes are interesting toys but of no military value", Marshall Ferdinand Foch, Professor of Strategy, Ecole Superieure de Guerre.

- "Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out in high school", New York Times editorial re Goddard's rocket work, 1921.

- "The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?", The associates of David Sarnoff in response to his urgings for investment in the radio in the 1920's.

- "Who the h— wants to hear actors talk", Harry M. Warner, Warner Bros. 1927.

- "I think there is a world market for maybe five computers", Thomas Watson, Chairman, IBM, 1943.

- "There is no reason for any individuals to have a computer in their home", Ken Olson, president, chairman and founder of Digital Equipment Corporation, 1977.

On the flip side of the coin, there are also those who have doggedly persisted in advancing new ideas that violate the second Law of Thermodynamics, so be alert.

8.0 HAVE UNYIELDING INTEGRITY

Admittedly, some integrity statements you will hear are market-driven and you may, over time, become numb to the constant messages. But this does not in any way detract from their validity and from the absolute necessity for you to maintain high integrity throughout your career. Whether you get caught or not, cheating is wrong. Character is important. The recent devastating effect that cheating and distorting the financial books has had on the corporate world and the US Wall Street should be ample evidence of the need for integrity.

But beyond this, the non-technical society is at the mercy of the technical person. Careless design and lazy analysis can cause social, economic and environmental damage to society and technical embarrassment to you and your company. It can even cause people's injury and death. You, as an engineer, must exercise unyielding integrity to do your best to prevent these things from happening.

One measure you can use is called the "Newspaper Test". Can your action or conduct stand the Newspaper Test, i.e., appear on the front page of the newspaper without legal or moral embarrassment to you or your company?

9.0 MAKE YOUR MANAGER A SUCCESS
A good manager wants to help you succeed, and you should in turn work to make him or her successful. Remember that your manager:

• Recommends high potential people for promotion

• Determines salary actions

• Writes performance appraisals

• Assigns work projects

• Recommends who to downsize.

Therefore, to regard your manager as your nemesis is a sure way to fail in your career. Don't do it. If you do not have respect for your manager or if you feel antagonistic towards him or her, transfer to another job. But remember the fault may be within you, so examine your reactions and motives carefully. Perhaps some real introspective thinking or attitude adjustment on your part is necessary.

Also, conduct your assignments so that you need little of the boss's attention. Be a "can do person".

10.0 SUPPORT YOUR UNIVERSITY AND YOUR TECHNICAL SOCIETY
You owe a great deal to your particular university and its professors who nurtured you and taught you the technical fundamentals of engineering. Support your university, visit it occasionally to give seminars, keep in touch with the faculty, talk to the students, give them some of the wisdom you have gained, encourage them. Both you and the students will find this personally rewarding. I guarantee, if your university wins a national championship, you will fly their banner proudly on your office door or cubicle.

Active participation in the technical society for your chosen field is an excellent way for you to grow and network. You will have the opportunity to meet and learn from highly skilled engineers, researchers and educators from other organizations. You will have the opportunity to present your own work at international forums and have it published in respected, refereed technical journals. As you grow, you will then be able to give back by helping younger engineers.

But this task will not be easy if you are in industry. Certainly you will be permitted to join the technical society, but attending major conferences, particularly overseas conferences, will likely be difficult. Travel and living budgets, time away from the job, limited number of persons permitted to go (i.e. slots allocated), etc. will be reasons you will hear for being denied permission to attend. But if you want to grow in this manner, you must persevere.

A suggestion is to ask a well-respected, well-known member of the technical society who works in a different company or agency to invite you to write a good technical paper or to organize a technical session at the conference. Then take this invitation letter to your boss. (Here is where networking helps, see Section 3). This is especially potent if your boss knows the outside member who is inviting you.

11.0 HAVE FUN

For goodness sakes, HAVE FUN in your engineering career. Enjoy your work. If you aren't really having fun, move on or change careers. I can't think of too many things more dismal than someone coming to work and hating it. Surely there will be some things about your work that you dislike. But on the whole, love your work. There are many exciting and challenging opportunities in engineering, so having fun can be easy.

12.0 MANAGE YOUR CAREER

Control your destiny or someone else will. Whether you work in industry, academe, government or as an independent agent, the primary responsibility for managing your career rests with you. What do you want? Where are you going? How are you going to get there? Neither the company nor your manager will "take care of you".

12.1 Myths about Career Development.

There are some general myths about career management that need to be dispelled. The myths presented below came directly from GE Human Resources to employees, both technical and non-technical alike. While all of the myths listed below are not true in all organizations at all times, they are generally valid regardless of your occupation, especially in today's business environment.

• Myth #1 — Do a good job and the company will "take care of you", or better yet, "take care of you for life". Nonsense. In reality no one will take care of you. You must take care of yourself. Do an outstanding job, better than anyone else. Even so, the days of companies providing lifelong employment are gone.

• Myth #2 — It's not what you know, but whom you know that counts. Baloney. What you know counts a lot. Whom you know and what they know about you also counts, but what you accomplish counts even more.

• Myth #3 — Career planning is my manager's job. No! Your manager's job is to lead. He or she often doesn't have the time, skill, ability or inclination to manager your career. Your manager could be a mentor and role model (good or bad). Only you know what you want and what you are willing to sacrifice to get it.

• Myth #4 — Nobody reads performance appraisals anyway. Not true. Many people do read performance appraisals — very closely. It may be the only thing they know about you and could be the ticket to a job interview. It is a written record that follows you.

• Myth #5 — You only get ahead if you work in the current "high visibility" area. Actually, it might or might not help you to work in such an area. Diversity in business experience is important. If your skills are better matched to another area, you could have better success there.

• Myth #6 — I would rather be lucky than good. Be good. No, be excellent or outstanding. Luck and timing are important, but your performance is the best influence on both. Results matter — again and again and again.

• Myth #7 — Just tell me the career path I need to be on to reach my goal. Sorry! There is no explicit career path or magic formula. Career management is an art, although central tendencies do exist. Seek help through your network (see Section 3.0) or your human resources representative.

12.2 Face Today's Realities.

A common answer I hear from young engineers is, "My goal is to be a manager". "That's fine,...but", I respond. Engineers need to realize that organizations are generally much flatter today with far fewer managerial positions available and fewer promotion grades from bottom to top. This means that you may have a difficult time achieving that goal.

On the encouraging side, leading edge companies are now making the much-discussed but previously impotent "dual career path" actually work. This will provide the opportunity for a non-manager (individual contributor) to achieve the same organizational level, salary and responsibility level of a manager. But whether you choose the management route or the individual contributor route as a career path, you will have to be proactive in managing your career to succeed.

12.3 You'll Likely Need a Mentor and a Champion.
There is a difference between a mentor and a champion. A mentor is a wise and trusted counselor, someone from whom you can learn the ropes. A champion is one who will promote your career in management circles. Don't underestimate the importance of finding both. You will be helped substantially if you can find a champion who notices the Four E's about you (see Section 5.2) and can pull you up through the organization. The fact is that pushing up from below is frustrating and often futile.

12.4 Diversify.
Many young, graduating engineers are hired into a company, placed into a technology group, grow in the group and then want to make a life-long career of this narrow area. Or far worse is the Ph.D. graduate who wants to make a career out of his or her narrow thesis topic. The reality is that today's engineering problems are multi-disciplinary (see Section 2.0).

While being a strong technologist in a narrow specialty can be very fulfilling, provide significant value and be just right for you, it is usually wiser first to MCBMA (manage career by moving around). Seek diverse assignments. Broaden your experience and become more valuable. Stretch yourself and grow. Then, if you choose to specialize, you will be better able to do your job.

Some call this getting "vitality". It is more than technical strength and vigor. It can enhance your capacity for survival and for having more fun through diversity. You'll see the bigger picture.

12.5 Get an Engineering License.
Sometimes, but not always, it is necessary for you to have an engineering license to do your job. In a large company or in a government job, having a license is often not necessary. In a small company, it is often necessary. If you want to work as an independent, it is vital to have one.

12.6 NEVER Stop Learning.
One of the biggest mistakes you can make in managing your career is to think that college 'commencement' means education 'finished'. The word 'commencement' means beginning, and that is how you must view your learning commitment. Successful engineers adopt an attitude of life-long learning. There are now so many opportunities available to you that there is no excuse for not continuing to learn.

These opportunities include company-paid education benefits, company training programs, on-line web courses, technical conferences sponsored by professional societies, workshops, technical journals that publish leading edge technical papers, etc. Technology will continue to progress, and those bright-eyed, bushy-tailed new engineering graduates will continue to nip at your heels, so learn you must.

CONCLUSIONS
Although there are no magic recipes that will absolutely guarantee your success in an engineering career, I do think there are definitive actions you can take that will significantly increase your probability of succeeding. I have listed twelve of these actions in this paper and suggest that you study them, discuss them with your manager, teacher or senior engineer/ mentor and put them into practice in your career. It is important to understand that when it comes to evaluating you, your managers will look for these three overarching attributes.

1. Technical knowledge and engineering skill. What is the level of breadth and depth of your technical knowledge and understanding and how well do you apply these to provide creative ideas and solutions in support of the business efforts?

2. Teamwork and leadership. How well do you maintain flexible and effective team relationships in accomplishing organizational objectives? How effectively do you communicate and lead?

3. Execution and Productivity. How well do you apply knowledge, understanding, judgment and initiative across multiple disciplines in planning and executing programs so that your customers get timely results in an efficient manner?

I wish you good success in your career.

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