"The Influence of Culture, Process, Leadership and Workspace on"

Dr. Leo E. Hanifin, University of Detroit Mercy

Dr. Leo Hanifin is a Professor in Mechanical Engineering at the University of Detroit Mercy, and has been the PI of UDM KEEN Entrepreneurship Grants for over five years, studying innovation and entrepreneurship. He was Dean of the College of Engineering and Science at UDM for the past 21 years August 2012.

Dr. Ross A. Lee, Villanova University

Ross Lee is a professor at Villanova University where he teaches Engineering Entrepreneurship, Sustainable Industrial Chemistry, Sustainable Materials, Green Science, and Biomimicry. Dr. Lee has over 36 years of industrial experience with the DuPont company (retired July 2009) spanning a wide variety of technology, product and new business developments including films, resins and innovative packaging systems. He has authored or coauthored over 20 patents and publications. In his most recent position, Ross was responsible for bringing new technology to packaging through open innovation and was instrumental in developing DuPont’s alliances with Plantic and Scanbuy. He has a Ph.D. in Organic Chemistry from Michigan State University and a B.S. in Chemistry from the University of Rochester. Ross and his family reside in Chesapeake City, Maryland.

Dr. Jonathan Weaver, University of Detroit Mercy

Jonathan Weaver, Professor of Mechanical Engineering at the University of Detroit Mercy, teaches a variety of courses – including courses on innovation and creativity, systems engineering, systems architecture, design of experiments, robotics, computer aided engineering, and the product development process. He holds a BSME degree from Virginia Tech, and MS and Ph.D. degrees in mechanical engineering from Rensselaer Polytechnic Institute. He is a Kern Entrepreneurship Education Network (KEEN) Fellow. Prior KEEN work includes the development of technical entrepreneurship case studies and extensive curricular materials related to innovation and creativity. The cases and many of the curricular materials may be found at http://weaverjm.faculty.udmercy.edu. Through his work with Innovation in Action, he has also conducted a number of innovation workshops for industry wherein the participants learn systematic innovation tools and apply them to their daily work.

Dr. Kenneth F Bloemer, University of Dayton

Ken is currently Director of the Innovation Center at the University of Dayton’s School of Engineering. The Innovation Center recruits real world engineering challenges from industry, entrepreneurs and non-profit organizations to be solved by multidisciplinary senior capstone teams. In addition, Ken teaches courses on innovation and is a frequent guest lecturer around campus. He has conducted innovation workshops for inventors at over 100 universities, federal labs and inventor clubs in the US, Canada & Scotland. Ken has a broad diversity of experience in Fortune 100 (Johnson & Johnson), business development and process improvement consulting (TechSolve), academia (University of Dayton, University of Cincinnati), government (US Air Force) and his true passion – inventing (Eureka! Ranch International and founder and managing partner of Bloemer, Meiser and Westerkamp, LLC). Ken has two issued U.S. Patents and serves on the Executive Committee and Board of the United Inventors Association. He has a Bachelors, Masters and Ph.D. in Industrial Engineering.

Ms. Cynthia C. Fry, Baylor University

Cynthia C. Fry is a Senior Lecturer of Computer Science and Assistant Dean for Special Projects in the School of Engineering & Computer Science at Baylor University. She teaches a wide variety of engineering and computer science courses, leads the iNova Weekly Innovation Challenge, and is a KEEN Fellow.
Current entrepreneurship education logically teaches engineering students to be entrepreneurs, yet most will work for medium to large sized corporations with cultures, processes and organizations that are far different than those of small entrepreneurial organizations. If American universities are to prepare highly innovative engineers for the corporate world, engineering faculty need to understand innovation and intrapreneurship (“i-ship”) in the corporate context. Through a grant from the Kern Family Foundation, four universities (Baylor, Dayton, Detroit Mercy and Villanova) partnered on such a study as a step toward developing curriculum that prepares undergraduate engineers to be more effective innovators and intrapreneurs in corporations. The overall collaboration of these four universities through the “Helping Hands Dense Network” is described in a previous ASEE paper. ¹

The three-year project focused on intrapreneurship is described graphically in Figure 1.

![Intrapreneurship Study Plan](image)

Figure 1 - Intrapreneurship Study Plan

The team recently completed Phase I, and this paper presents a summary of its findings. The purpose of Phase I is to expand the knowledge and understanding of i-ship and innovation as they relate to engineering education outcomes. It is hoped that those findings will define learning outcomes of engineering education programs (Phase II). This in turn will guide the development of curriculum and experiences at universities (Phase III) that will make their graduates more effective intrapreneurs and innovators in the corporate world. A secondary benefit from the direct dialogue with industrial participants is the increased understanding by industry leaders of how the four areas of culture, leadership, processes and work space impact their innovative performance, and how they can be more effective in their recruiting of engineering graduates with the greatest potential to be effective innovators and intrapreneurs in their companies.

Relevant Literature

Numerous authors have written books on the topic of corporate innovation. However work to translate their findings into engineering competencies and learning outcomes that can result in improved intrapreneurship capabilities of is surprisingly sparse. The team’s literature review discovered no publications aimed explicitly at defining educational outcomes to support intrapreneurship.
While there are at least thirty papers in engineering education literature that refer to intrapreneurship and the need for an entrepreneurial mindset in corporations, the authors were not able to find any papers that discussed the roles of engineers as innovators in corporations nor the substantive differences between entrepreneurship and intrapreneurship. Most papers focus on the methods and content of courses to develop innovative or entrepreneurial skills/mindset, with a casual mention that the course outcomes are also valuable to intrapreneurs in corporations of all sizes. There was also a lack of any explanation of what is meant by intrapreneurship. One paper referred to “intrapreneurship curricular elements,” and the “intrapreneurship lens,” but failed to describe what was meant by either term. Some papers describe entrepreneurship and entrepreneurs, and then attribute all entrepreneurial characteristics, skills and attributes to intrapreneurship and intrapreneurs without any justification of that transference. Others, like Mehta and Abbott, clearly acknowledge that there are differences between entrepreneurship and intrapreneurship (and even mention Pinchot’s seminal work on intrapreneurship), but do not discuss those differences in their paper.

Zappe, Hochstedt and Kisenwether conducted a study of faculty beliefs regarding entrepreneurship and design education. One of their questions asked 37 entrepreneurship and capstone design faculty members to choose whether Entrepreneurship programs should “focus on: Intrapreneurship Only versus Entrepreneurship Only,” or somewhere along a scale from zero (intrapreneurship only) to 100 (entrepreneurship only). An answer of 50 means “their responses tended to fall between Intrapreneurship Only and Entrepreneurship Only.” The median for entrepreneurship instructors was 60 (slightly skewed toward entrepreneurship only), while the capstone design instructors’ medium response was 50. The range of responses for both groups was from 18 to 100, seeming to indicate that some faculty members held strong views regarding a clear distinction between what should be taught to educate entrepreneurs and intrapreneurs. However, this paper (nor any others that were discovered) did not discuss what those distinctions might be.

While all of these papers are extremely valuable in disseminating methods and content of entrepreneurial education, they do not directly address the key foci of this research project: how do American companies innovate and what are the competencies that would make our graduates effective innovators and intrapreneurs in those corporations?

In addition to the scholarly literature regarding innovation and intrapreneurship in corporation there are two other sources of insights that are valuable to this study. The first is the books written on innovation in recent years by such authors as Kelley, Brown and Christiansen. The other is the array of books and literature that relate to the specific areas discussed in this paper such as prototyping (Christie) and confidence/motivation (Pink). These sources are discussed in the sections relating to those topics.

Phase I Methodology

The paper is based on interactive research through the engagement of leading corporations. The authors’ observations and corporate presentations and demonstrations during this engagement, as opposed to quantitative data and analysis, have provided the findings of this paper. The authors embrace the value of “story” (as described by Pink and Kelley) as a powerful method of
discerning and conveying rich context and wisdom, separate from the more traditional engineering methods employing data and quantitative analysis.

The study team was joined in this research by innovation leaders from over a dozen companies, selected as a representative sample of innovative corporations from America. These included companies from a wide array of industries including aerospace/defense, automotive, chemical/materials, construction, food/consumer, information and medical devices. The team conducted in depth visits and discussions with ten of these partners: BASF, Campbell Soup, Comcast, DuPont, Ford, IBM, IMDS, Lockheed Martin, Pankow Builders and the US Air Force. The leaders with whom the team met were selected by corporate executives as their best innovation leaders. In all, the team met with over 100 participants who held titles that ranged from CEO, Corporate Vice President for Worldwide Product Development, and VP Engineering and Architecture to Master Inventor, Director - Advanced Product Creation, Director - Technology and Development, Colonel, USAF, and even “Chief Skunk.”

These innovation leaders were asked to create an intensive exchange with the study team that included two major elements. The first was the presentation of what they considered their best practices in five broad areas as they impact innovation and intrapreneurship: leadership, process, culture, organization and workspace. While they were asked to describe these corporate aspects systemically, they were urged to emphasize in depth stories of specific examples.

After these ten visits, the team reviewed these practices and effective cases of how each of these five areas enabled innovation and intrapreneurship. It was decided that the visits had not yielded sufficient results in the area of organization to warrant presentation in this paper. That is not to say that organization is not important. (In fact, some elements of organization are discussed within the finding of the other four areas.) However, the discussion of corporate innovation and intrapreneurship below focuses on the four remaining areas of culture, process, leadership and workspace. Each of these areas is discussed below, primarily through the use of cases and stories that richly reveal the findings of the study team in the specific corporate context. The examples presented were selected by the authors as those that were most valuable to understanding that particular aspect (culture, leadership, etc.) of the corporate milieu at it related to the engineer’s role. As such, they are not global “best practices” in the normal sense of the term. Rather, they are the examples that were deemed as the most illuminating to engineering educators from the many cases and stories presented during the corporate visits.

Competencies that Support Corporate Innovation

In addition to our discussion of these four factors’ impact on corporate innovation, the second major element of each corporate visit was each industrial partner’s recommendations of competencies, mindsets and knowledge for future engineering innovators, especially those not provided by today’s engineering education. Both corporate innovation leaders and recent engineering graduates provided over 160 recommendations. The second part of the paper presents a summary of their answers and reflections of the authors in the section title “The Voice of Corporate Innovation Leaders.”
The Culture of Innovation

In order to compete effectively in today’s global economy, companies must foster a culture that encourages the development of certain intrapreneurial characteristics among its employees, especially its engineers. According to an article by Lisa Quast in Forbes magazine, “the characteristics and skills necessary for becoming a successful intrapreneur include:

- Knowledge of the internal and external environment
- Visionary and willing to challenge the status quo
- Diplomatic and able to lead cross-functional teams
- Ability to build a professional support network
- Ability to persevere, even in the face of uncertainty.”

While large organizations often recognize the need for commercial vitality and have the resources to implement innovation, many lack the corporate culture that fosters innovation and the continued growth of these intrapreneurial characteristics. Because innovation is inevitably linked to risk, many companies may consequently avoid it. Much research has been done on the combination of cultural factors and innovation in companies that are successful at identifying opportunities that lead to commercialization. Through this research many of the elements of corporate culture which promote innovation have been identified. These elements include:

- Balanced autonomy – freedom to recognize a challenge, and freedom to attack that challenge
- Personalized recognition – rewarding individual for their contributions
- Integrated socio-technical system – balance emphasis on both the technical side and the social side of the organization
- Continuity of slack – having a cushion of resources available over time

Historically, many companies, like IBM and Apple, have seen their fortunes overturned because of their inability to understand the importance of the corporate culture in innovation. Fortunately, this does not have to be a fatal misunderstanding, as the current success that both IBM and Apple demonstrate. During the study teams’ visits to the ten corporations, it was clear that many of these elements that promote innovation exist in each of them. In the case of IBM, their Global Solutions Center embodies all of these elements through the organization of the company, the environment for their employees and customers, and the culture of innovation within the company.

Innovation Culture at IBM

IBM started as a company known for its innovations in hardware, but has continued to apply an innovative approach to their own processes and organization, and to developing a culture that provides a catalytic environment conducive to innovation.

The study team visited the IBM’s Global Solutions Center in Coppell, Texas, and met with many key innovation leaders there. These included one of IBM’s Master Inventors and Distinguished Engineers, along with their Public Sector Solutions Manager, their CTO of Global Education, their Manager of the Austin IBM Innovation Center and Worldwide Virtual Innovation Center,
an IBM Client Executive and a Solutions Center Project Leaders. In depth presentations, and discussions regarding innovation processes and solutions, local and global organization, leadership, and hiring and training programs made it clear that the culture of innovation at IBM is systemic and pervasive. It is evident in their organization, their corporate strategies, and their expectations for their associates.

**Corporate Structure**

As a company that provides solutions to customers, IBM’s innovation structure allows flexibility in their ability to respond to their clients. IBM has six major divisions:

- Software
- Global Business Services
- Sales and Distribution
- Research
- Global Technology Services
- Systems and Technology

It is the combination of these six divisions and their emphasis on collaborative and cross-disciplinary project work that provides IBM’s with a very strong foundation for their culture of innovation. Building on that foundation, IBM has assured that innovation is pervasive throughout the corporate structure by creating three academies:

- Academy of Technology (AOT) – One thousand technology leaders meet to advance the understanding of key technology areas of interest to IBM. The AOT improves communication globally across IBM’s technical community, fostering collaboration across members. IBM also has 44 regional affiliates who help disseminate technical skills and knowledge, and enable the regions to focus on technologies of most importance to those regions.

- Industry Academy – The IBM Industry Academy is composed of sellers and consultants who are recognized within IBM for their deep and insightful knowledge of specific industries. They meet regularly to adopt strategic projects.

- Council for Innovation Leadership – Made up of IBM’s Master Inventors, this body drives standards for patents, disseminates exemplary patents, enables the development of patent filings and defines key areas where patents will help drive activity in areas of interest. (Granting of the title Master Inventor is based on number of patents, mentoring to help others learn to patent, and patent impact on IBM revenue. It must be renewed after three years based on recent performance.) This body meets regularly to review patent production and to actively seek new areas of interest to IBM.

Patents are clearly a key element of IBM’s innovation process. According to the January 11, 2012 article in Bloomberg, in 2011 IBM won a record number of U.S. patents for the nineteenth year. As an incentive to pursue patents, “IBMers” receive a $1,500 for their first patent filed; and, to encourage collaboration, these awards are not reduced or shared if there are four or fewer names on the patent. Finally, if the invention generates revenue, the inventors may share in the proceeds. Used to maximize strategic benefit, IBM employs a rapid process to assess patentability early in the development process, and a clear process to secure patents (See Figure
2). While this process may not be unique, the fact that it is clearly and pro-actively conveyed to all employees underscores IBM’s strategy of employing patenting as a driver of innovation, and reflects IBM’s culture of innovation.

**Figure 2 - “The process of invention, from idea to patent” (from IBM)**

These organizations and policies both reflect and deepen the culture of innovation at IBM.

**Innovation Cases**

During the site visit, IBM’s Global Solutions Center described in detail three programs of interest: the Smarter Cities Program, Watson, and the Intelligence Operations Center. Each of these examples is of interest in learning how IBM has developed a culture of innovation that it directly connected to and learning from current and potential customers and markets.

**Smarter Cities Program**: IBM sends out teams to cities as part of their Smarter Cities Program. These teams help the cities’ leaders to understand how information technology can be used to renew/revive/improve their vitality, irrespective of whether or not they employ IBM technology. This also provides valuable insight to IBM; returning teams provide the company with deeper and broader understanding of urban and human needs, and how IBM might apply what they have learned to their innovation process and the development of new offerings.

**Watson**: Watson is a cognitive system developed by IBM capable of answering questions posed in natural languages. In 2011, in a test of its abilities, Watson competed on the quiz show, *Jeopardy*, in the show’s only human versus machine competition to date. Watson is now
available to companies, industries, communities, in part or in whole, to help them intelligently manage the ever-growing amounts of data available to them.\textsuperscript{26}

**Intelligence Operations Center:** An overview of the Intelligent Operations Center was provided in relation to a project in Rio De Janeiro. The City of Rio de Janeiro noticed a need to avert weather-related crises. IBM developed a system that could quickly alert city administrators of the status of imminent weather-related activities. IBM’s initial engagement was to understand the needs of the city, listen, ask questions, and test concepts. The concepts developed were expanded into a general intelligence operations center that could be used by any city to continuously update administrators on current conditions in each area. This concept has been expanded to a platform that can be used to continuously monitor and guide responses to a wide variety of activities and conditions.

This development initiated an architectural methodology for client engagement:

- **Phase 1:** Focus on understanding and listening.
- **Phase 2:** Focus on reflection – what was heard, brainstorming, developing alternatives
- **Phase 3:** Focus on redesign. The client is engaged throughout.
- **Phase 4:** Focus on the architectural design.
- **Phase 5:** Focus on testing.
- **Phase 6:** Focus on deployment.

The important elements of this process are its emphasis on an iterative, deep engagement with the customer and the systems/architectural thinking regarding the solution.

**Innovative Culture at IMDS**

Another of the companies visited, Innovative Medical Device Solutions (IMDS), demonstrates an innovation culture that results in consistently shorter cycle times (e.g. typically 12-14 months vs. 32 months for a key competitor) in a regulated biomedical field. IMDS provides medical implant solutions including unique testing technologies. Their culture is one that promotes a customer focused, make-it-happen innovation mindset - effectively, quickly, with uncompromised performance and safety, all accomplished through cross discipline involvement and highly flexible and responsive operations. In fact, their leaders explicitly stated that “Innovation is infused in our culture. We need to celebrate all innovation including customer service, process, product, etc. and infuse the innovation culture to all aspects of the company.” (Interview of IMDS executives and engineers, July 17, 2012) A few examples illustrate how far they have come in doing just that.

When faced with the prospect of off-shore manufacturing, IMDS sought ways to innovate the existing manufacturing processes and make them superior to off shore in both economics and performance. One aspect of this involved centralized control of remote inspection operations so that “lights out manufacturing” could occur 24/7 with extreme efficiency and safety but without operators at the remote location. This points out the need for engineering innovators to consider innovations in all phases of product realization, including production. Such innovations may be just as valuable to the customer as product innovations as they can deliver products faster, better
and cheaper . . . all of which may be the difference in how the customer receives the product, and therefore the difference between success and failure of the product.

Another aspect of IMDS’ unique innovation culture is their connection with OEM customers via “co innovation centers.” These centers are located near OEMs that are the IMDS customers; there collaborative teams innovate without any “hard line financial or business agreement.” These collaborations are based on open innovation alliances with the hope of securing supply agreements. These bring in cross disciplines for the design and implementation of the innovation ensuring that manufacturing, sales and engineering are actively engaged right from the start and that the entire team develops, understands and OWNS the innovation. Ownership of outcomes was a key skill stressed. (Here the word “ownership” does not refer to ownership of the intellectual property (IP), but “buy in” of the innovation process.)

Innovation spaces at IMDS also help to promote this culture. These include curved walls that can be easily written on by anyone to get feedback on emerging ideas. Cross pollination of ideas is strongly encouraged to get at the very best and most effective solution. IMDS stressed that innovation is everyone’s job. This is key attribute attributed to the most innovative companies (Dyer, Greger, Christensen). Other key skills thought to be needed in successful engineers at IMDS include: critical thinking; “T “shaped engineers who can bridge the gap to other functions including sales, and business; engineers who can see the key elements in preliminary designs to formulate a solution without requiring excessive detail (good at “napkin designs”).

Innovation Processes

The study team’s visits to ten corporate partners involved extensive discussion of many processes aimed at the development of innovative products. Several valued and developed the ability to rapidly prototype to both explore and test new concepts and offerings. The specifics of such prototyping processes differed depending on the type of product offering and the marketplace dynamics. These differentiated prototyping strategies are consistent with the various prototyping strategic factors reported by Christie et.al in their excellent review of prototyping strategies. Four examples will be shared to illustrate this. One involves new material offerings at DuPont. Another involves prototyping and flexible product platforms for new communication services at Comcast. A third involves new consumer products at Campbell Soup. The fourth example of innovation processes is a discussion of the processes at the iconic innovation organization, the Lockheed Martin Skunk Works © that employs a variety of effective innovation processes that have been honed over decades.

DuPont Innovation Processes

DuPont has a reputation of being a science based company. Their approach to innovation through science-based modeling and prototyping processes builds on this. When faced with the challenge of developing bullet resistant protective apparel that was lighter weight and more comfortable to wear for the military and local enforcement agencies, DuPont started by developing a scientifically valid virtual model for material deformation to a fired bullet. This is an extremely sophisticated model that links material parameters with state of the art measurements for deformation (see Figure 3). Several iterations are used to validate the model
and establish predictive capability. Once validated through physical tests that employed advanced high speed video recording, this model was then used to screen a wide variety of material combinations including those that were not intuitively obvious. In fact, the unique nature of the ultimate combination that led to lighter weight but highly effective apparel was patentable. Similar approaches were used to develop improved puncture resistant tires and a new catastrophic storm resistant structure within a home.

![Figure 3 - Time Lapse Video Showing Bullet Hitting Bullet Resistant Sheets](http://www2.dupont.com/personal-protection/en-us/dpt/video/armor-technology-center.html)

DuPont’s sophisticated modeling and physical measurements results in mapping the actual deformation with material parameters to enable the design of new, effective materials and combinations.

The overall process involves the following steps:

1. Understand the science and the problem, especially the physics and chemistry and controlling parameters

2. Model and test the materials and product (both computer and physical models)

3. Create the opportunity for innovation
   a. What material solution will work?
   b. What design solutions will work?
   c. Quantify the relative contributions of materials and structural components to focus innovation efforts
   d. Exploit interrelationships between materials and structures; for example, apply knowledge of materials to take advantage of a physical mechanism.

4. Screen ideas to determine the best materials and designs, and the best and most cost effective solution
5. Quickly demonstrate a prototype.

6. Validate via experiment.

7. Propose a hypothesis; collect data; analyze the data; and draw conclusions.

This process is unique, amongst those seen at other corporations that were visited, by the sophisticated level of the science-based virtual modeling that is honed to established predictive capability via the equally sophisticated physical measurement techniques.

Engineering skills that are most important to enable this include strong, solid mathematical and science skills to address the rigor needed to establish valid and predictable virtual models; strong associative skills to be able to see where candidate material options might exist in order to be included in the test; and strong analytical skills to develop the sophisticated physical measurement techniques, and interpret and process the data to enable innovative solutions.

**Comcast Innovation Processes**

Comcast employs two effective methods to innovate:

1. a process that ultimately can integrate a new concept into a business aligned with its core platforms.
2. flexible product architectures that include platforms that allow rapid development and field testing on innovations

Before describing these, it is important to understand the importance of ventures and platforms. At Comcast, innovations get their start as ventures that then become integrated with lead businesses. Comcast regularly creates both internal and external ventures. An internal venture is funded as an independent enterprise and then brought back once it looks viable. Ensuring that it ties to core competencies and platforms that support existing businesses is essential in this process. An **internal venture** is separate from the main businesses and may even be moved off site and given a great deal of autonomy. An example was a new TV guide venture that developed a software solution, connecting home-based applications to the cloud, via high-speed data connections. In this case, the technology was successfully tested first as a venture and is now being integrated with the existing strategic business. An **external venture** can include either acquisitions, strategic investment, or spinouts. Most work with external ventures is handled through Comcast’s venture capital arm. Comcast Ventures is a combination of Comcast and NBC ventures organizations, where they focus upon investment strategies targeted at new technologies.

The overall venture process typically follows:

1. Create independent venture
2. Cooperate with other businesses
3. Complete “co-projects” with businesses
4. Integrate into infrastructure

The most valued technologies are those that can lead to multiple opportunities and that link to existing core **platforms**. For example there may be a technology that can improve today’s operations in the near term (1 year) and yet provide the basis for new products in the longer term
(2-3 years). An example would be a technology platform built around the cloud based computing infrastructure and sensors. The near term application is for home communication/entertainment applications. The longer term application might be a whole new market space involving health care. Such a platform might link to the existing TV entertaining platform, with a health care component tied to the existing Xfinity™ Home (home security) platform. Such a system might note unusual patterns of movement of an elderly patient with dementia that may reflect a danger to the patient (such as lack of motion in a basement late at night), and alert caregivers or emergency services. Linking into a core set of competencies and platforms helps establish common standards so that new systems can talk to old ones or ones in different market spaces. Platforms also enable a link to business strategies that helps assure a new venture can gain strategic business support. Platforms also provide a tool kit. New innovations can come from mixing and matching existing technologies.

CHIP Innovation Platform

Building on these concepts, Comcast has developed a unique prototyping process and product architecture as a flexible platform. This platform supports extremely rapid development and testing of new hardware to provide new communication functions. Prototypes can even be field tested in people’s homes. It is called CHIP – Comcast Hardware Innovation Platform. CHIP enables extremely rapid prototyping and field testing that can reduce the product development time to one year for smaller devices. An extremely valuable element of this process is that CHIP allows Comcast to rapidly validate interest and functionality by a rapid pilot introduction of the function into many homes. An example is a concept of Lego™-like designs based on the DOCSIS operating system, coupling distributed components at high data transfer rates. Low intelligence, distributed devices can be linked to a centralized gateway, enabling a final product providing higher value, created using the combination of local and remote interfaces. Figure 4 shows this and other components in this flexible platform.

Rapid prototyping and quick testing are key. The mantra is to fail cheaply and rapidly to ultimately deploy new successful applications. The process, led by Michael Cook, VP of Video Technology at Comcast, looks at technical add-ons to existing hardware systems that have an attractive value proposition, a short time to completion, differentiated value, and an attractive opportunity.
Engineering skills most important for this process include design skills developed by involving engineering students in design courses; a solid knowledge of how Linux works; the ability to code in multiple languages including C/C++ and JAVA; sequential vs. object-oriented programming where object oriented design and programming is the preference; the ability to communicate (as in the DuPont input); critical thinking and people skills.

**Campbell Soup Company Innovation Processes**

The Campbell Soup Company employs many effective approaches in their intrapreneurship process – approaches that students are typically not exposed to until gaining years of experience in industry. A thorough description of their process creates overlaps with the topics of leadership, organization and culture; those elements are included here to provide the entire Campbell Soup innovation story. The processes described were conveyed to the authors by Campbell Soup’s Director - Global Packaging Research & Development; a Program Manager and Innovation Team Member; the Vice President - Global Engineering; and an R&D Program Manager.

*Innovation Story: Remaining Relevant as Canned Soup Sales Dwindle*

Before describing the actual innovation process at Campbell Soup Company, a little background information is appropriate. Founded in 1869, Campbell Soup Company is a global manufacturer and marketer of high-quality foods and simple meals, including soups and sauces, baked snacks, and healthy beverages. Campbell’s products are sold in more than 100 countries under a variety of market-leading brands, including “Campbell’s,” “Pepperidge Farm,” “Arnott’s,” and “V8.” Campbell Soup Company has more than 7,000 employees worldwide, including approximately 140 engineers.

During its earlier years, canned soup was Campbell’s principle product. North America has seen a steady decline in canned soup sales for many years. With just over half of Campbell’s North American sales now in soup, the company has found it essential to innovate into new and adjacent markets and to attract different types of consumers in order to remain strong. The current CEO, Denise Morrison, has placed enormous focus on driving top line (revenue) growth via innovation. This requires dealing with some fundamental process issues and culture. Morrison says “In order to develop new products, services, and experiences that will truly engage consumers, one thing is very clear: Innovation must be cultural.” (From presentation shown during I-ship Team visit to Campbell Soup, December 7, 2012) Campbell’s Skillet Sauces are an example of a new Campbell’s product that resulted from the company’s recent innovation activities. The process that was used to develop this new product is summarized in the remainder of this section.

The Campbell’s innovation process begins with the top leadership. They meet to discuss all the perceived opportunities and choose a broad category or segment which will be pursued. Then for each resulting innovation project, they develop a mission statement around which a dedicated innovation team will be formed. The mission statement often includes aspects related to definition of the target consumer and/or the product category. In the case of the Skillet Sauces, the mission was based around the fact that millennials experience and enjoy all types of culinary
experiences at restaurants, but typically don’t know how to make the same dishes at home, and aren’t willing to dedicate the time to cook “from scratch.”

Next, a dedicated team of five is formed around each innovation project. One team member is chosen from each of five specialties: consumer insights, product development, chef, marketing (typically a brand manager), and package engineering. It was also noted that these team members are all well-seasoned, highly regarded people who can work effectively in multidisciplinary teams. An innovation leader pointed out that they need to have exceptional interpersonal skills, a strong business acumen, and an ability to “connect the dots” across many stakeholders and viewpoints. Successful team members are not just good technical problem solvers, but also understand how things connect to the business, to the market, and to consumers. The chosen team members are “pulled” from their regular jobs and assigned to work 100% on the innovation project for the project’s one to two year duration. The early cultural reaction to such an innovation assignment was that it was a distraction from progressing within one’s specialty; more recently, it is recognized as an honor and a privilege to be asked to serve on an innovation team.

Once a project is identified and the team has been formed, the four major steps in the Campbell’s innovation process are Discovery, Translation, Early Development, and Late Development. These steps will be summarized below for the Skillet Sauces project. (It is important to note that this description of the Skillet Sauces project deals primarily with the packaging of this product, and not the culinary innovation that was done elsewhere.)

**Discovery**

The project team that ultimately developed the Skillet Sauces began by asking what the problems their target consumer faced. This research involved a variety of tactics — such as interviewing shoppers, watching people shop, going shopping with people, going into homes and watching how people live and prepare meals. The team tries to look for qualitative data rather than the quantitative data that many corporate marketing departments churn out. The key outcome of this consumer research stage is a deep understanding of what would compel a consumer to buy the new product. Amongst other things, the Skillet Sauces team noted that soup is not competing with other brands of soup, but with pizza, restaurants, subs, and other convenient, up-scale make-at-home products (“share-of-stomach”). They also noted that often a meal for one or two was needed, not a family sized meal. A mantra of the discovery phase is “Learning to focus.”

**Translation**

Once the consumer research is done, the next step involves translating that knowledge of the customer into problems that the team can work on and solve. Most engineers are trained in problem solving — but very few are trained in problem definition. The successful intrapreneurs at Campbell’s are good at this translation of consumer insights into solvable problems. The Skillet Sauces team translated their insights into something along these lines: an opportunity to easily use a skillet sauce to provide a quick, healthy, right-portioned restaurant-like meal with little hassle and few ingredients required.
**Early Development**

As the project progresses, concepts are generated to address the problem at hand. This is a highly iterative process with consumer feedback sought at several points along the process. The team also needed to keep in mind the alternative package types (cans, pouches, plastic containers, etc.), processes (retorted, acidic/non-acidic, refrigerated, hot fill, etc.) and product platforms (soups, sauces, beverages, etc.) they were working with. Intrapreneurs need a good sense of engineering judgment and an ability to apply a ‘litmus test’ to the reasonableness of an answer.

The Campbell early development phase makes use of three levels of virtual prototypes of increasing complexity as the project evolves. These levels, in order of complexity, are 2D concept sketches, 2D illustrated concepts, and 3D rendering. 2D concept sketches are basic, single color hand sketches. 2D illustrated concepts can be done by hand or on a computer, use multiple colors/shading, may include branding/mapping of graphics, and either has a hand drawn appearance or very realistic digital representation. 3D renderings are full-color, completely realistic rendering that may be either static or animated. Successful intrapreneurs at Campbell’s are good sketchers and are proficient with digital mockup tools (Campbell’s uses SpaceClaim to quickly create their virtual 3D models and KeyShot to render them). An example rendering from a different innovation project is shown in Figure 5.

![Figure 5 - 3D Prototype Rendering](image)

The Campbell’s team uses their own 3D prototyping capability now to bring this into the early development phase in order to explore new concepts. This facilitates use of the prototypes to get interactive upgrades on the concept.

**Late Development**

Once the team is reasonably confident on the direction they are heading, they proceed with late development activities. These activities typically include three types of physical prototypes (which are, of course, more expensive than the virtual prototypes used in the Early Development phase). The three types of physical prototypes are 3D mockups, 3D modeling, and prototype units. 3D mockups merge new and existing package formats by adapting existing packages with new graphics. Figure 6 shows a 3D mockup done for the Skillet Sauces using a stick-on label. This phase also includes an active dialog with professionals responsible for production of the packaging and the food product and combination of the food and packaging to consider such issues as cost, production flexibility, sterilization and recyclability of the packaging materials.

![Figure 6 - 3D Mockup](image)
3D models are hands-on models closely simulating the actual product in fit and form, and sometimes in function. Sample 3D models for other innovation products are shown in Figure 7. A 3D laser scanner may be used to analyze competitive product packages during this phase of the project.

The final prototype stage involves fully functional parts validating the final design.

The innovation team works closely with a launch team to bring the new product into production. Once a product is ready to launch it is rolled out through Campbell’s vendors. Campbell’s Skillet Sauces should appear on a store shelf near you very soon!

**Lockheed Martin** Innovation Processes

In 1943, Kelly Johnson and his team designed and built the XP-80, a prototype of the nation’s first combat jet aircraft, in just 143 days. This project marked what would become the Skunk Works® with Johnson at the helm. Today, Lockheed Martin’s Skunk Works®, which is also known as Advanced Development Programs, continually pushes the envelope of what is possible in manned and unmanned military and civilian flight.

Innovating in the domain of very complex products (such as aircraft) brings along a conundrum. The core business requires delivering these products at exceptional quality and reliability with all conceivable failure modes considered and protected against as best as possible. This inherently results in rather long execution times with a very complicated and detailed systems engineering process tracking many thousands of requirements, and a bias towards evolutionary system change. The conundrum is that innovating by following the same development process would result in lengthy development times and numerous expensive late design changes. As a result, asking the core business to do innovation generally doesn’t work. Isolating innovation far from
core business does not work either. Innovation needs to leverage core business capabilities. The Skunk Works® response to this conundrum is their up-front development process that is used to quickly explore and prove out new, innovative ideas outside of the mainstream development and production system that approved projects must go through. The Skunk Works® provides an environment where people are free to take risks and “successfully fail” - provided they learn from it. The process leverages the core business by innovating only in areas of the aircraft essential to the new idea, while reusing existing components/technologies elsewhere.

The Skunk Works® process follows Johnson’s 14 rules and practices:

1. The Skunk Works® manager must be delegated practically complete control of his program in all aspects. He should report to a division president or higher.

2. Strong but small project offices must be provided both by the military and industry.

3. The number of people having any connection with the project must be restricted in an almost vicious manner. Use a small number of good people (10% to 25% compared to the so-called normal systems).

4. A very simple drawing and drawing release system with great flexibility for making changes must be provided.

5. There must be a minimum number of reports required, but important work must be recorded thoroughly.

6. There must be a monthly cost review covering not only what has been spent and committed but also projected costs to the conclusion of the program.

7. The contractor must be delegated and must assume more than normal responsibility to get good vendor bids for subcontract on the project. Commercial bid procedures are very often better than military ones.

8. The inspection system as currently used by the Skunk Works®, which has been approved by both the Air Force and Navy, meets the intent of existing military requirements and should be used on new projects. Push more basic inspection responsibility back to subcontractors and vendors. Don’t duplicate so much inspection.

9. The contractor must be delegated the authority to test his final product in flight. He can and must test it in the initial stages. If he doesn’t, he rapidly loses his competency to design other vehicles.

10. The specifications applying to the hardware must be agreed to well in advance of contracting. The Skunk Works® practice of having a specification section stating clearly which important military specification items will not knowingly be complied with and reasons therefore is highly recommended.

11. Funding a program must be timely so that the contractor doesn't have to keep running to the bank to support government projects.

12. There must be mutual trust between the military project organization and the contractor, the very close cooperation and liaison on a day-to-day basis. This cuts down misunderstanding and correspondence to an absolute minimum.

13. Access by outsiders to the project and its personnel must be strictly controlled by appropriate security measures.

14. Because only a few people will be used in engineering and most other areas, ways must be provided to reward good performance by pay not based on the number of personnel supervised.
Polecat Demonstrator Development

The recent development of the Polecat Demonstrator, shown in Figure 9, will be used to illustrate some of the key aspects of the Skunk Works® development process. The Polecat was an effort to better understand the flight dynamics of a tailless unmanned air system as well as to field the next generation of structural composite concepts. It was specifically intended to verify three things: new, cost effective rapid prototyping and manufacturing techniques of composite materials; projected aerodynamic performance required for sustained high altitude operations; and flight autonomy attributes.

Figure 9 - Lockheed Martin Polecat Demonstrator

The Polecat development worked to a minimalist set of requirements that included:

- Cruise to 60,000 Feet
- Endurance – 4 Hours Minimum
- Payload of 1,000 Pounds
- “Autoland”
- Configurable Payload/ Weapons Bay
- 50% Improvement in Development Cost

Some of the developments made in the composites area included:

- Extensive use of soft tooling (high density foam) to cut lead times in half
- Minimization of up-front nonrecurring costs
- 3X Reduction in tooling costs
- Bonding upper skins eliminated 8,000 fasteners
- 50% reduction in touch labor
- Airframe fabrication costs reduced 30%
As shown in Figure 10, the Polecat project took 18 months from go-ahead to ready-for-flight. It was executed with internal funding.

Some of the key attributes of the polecat development that can be translated into engineering competencies of successful intrapreneurs are summarized in Table 1.

Table 1 - Project Drives Competencies

<table>
<thead>
<tr>
<th>Project Characteristics</th>
<th>Engineering Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leverage existing technologies (Polecat used existing Twin FJ-44 3E Engines)</td>
<td>Don’t reinvent the wheel; recognize when and where innovation is essential to moving forward</td>
</tr>
<tr>
<td>Avoid requirements creep</td>
<td>Tolerance for ambiguity and avoiding striving for perfection</td>
</tr>
<tr>
<td>Continually spiral and enhance capabilities</td>
<td>Build many quick, inexpensive prototypes each designed to lead to some key learning</td>
</tr>
<tr>
<td>Leverage new technologies (key enablers on Polecat included rapid prototyping, next-generation composites, and natural laminar flow)</td>
<td>Maintain currency of technological developments - and be able to synthesize new possibilities that those developments enable</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Leveraged simulation platforms such as Matlab and Simulink to keep software integration on pace with vehicle development</td>
<td>Fluency in applying such software to perform virtual prototyping</td>
</tr>
<tr>
<td>The airplane was built 50 feet away from where the engineers were designing the airplane.</td>
<td>Understanding that manufacturing methods and processes (and availability of specific prototyping systems) must be considered as both prototypes and final products are designed.</td>
</tr>
</tbody>
</table>

Leadership in Intrapreneurship and Innovation in Corporations

The “I-ship Team” encountered examples of effective leadership in many corporations that were visited and the people that were interviewed, but two stand out as particularly illuminating of what it takes to accomplish innovation in the face of great barriers. They both involved individuals who had tremendous confidence and tenacity as individuals, but also had the wisdom to convince key partners to drive the innovation forward with them. One such person was Calvin Yoshida at Pankow Builders; the other was Derrick Kuzak at Ford Motor Company.

Innovation at **Pankow Builders**: Shuffling the Construction Steps for a High Rise Building

Before telling the actual story of Calvin Yoshida’s leadership in shuffling the construction steps for a high rise building, it is valuable to understand a bit more about Pankow Builders and how they manage large construction projects. Pankow is a self-described “construction solutions company” that operates business units in Southern and Northern California and Hawaii. They don’t design buildings themselves, but they employ a variety of collaborative models to lead in the design and construction of buildings, typically very large buildings and complexes. As such, Pankow’s innovations are most often in the areas of construction processes and materials. In fact, they are widely recognized for their innovations in precast structural modules that reduce cost and increase efficiency, allowing such unique concepts as “overbuilding” existing buildings while they remain open.

Building a large building using any method requires the collaboration and harmonious choreography of many players in the process. In fact, the production of a large building may involve 100 entities, including up to fifteen consultants, suppliers, customer-owner and as many as sixty subcontractors. All issues that occur during building are best solved by the collaboration of the team. Win/win is important, and super egos often create super problems.
The degree of collaboration between team members may, to some degree, depend on the level of collaboration offered in the past between people and organizations that are in the current partnership. The entity or person making an error or omission today may be not given much support if they were not cooperative when someone else made an error in the past. This lower level of cooperation may impede innovation. The lesson here is that people don’t want to cooperate with or listen to partners who were uncooperative in the past when someone else made a mistake or omission. This lesson is also discussed by Tom Kelley in his popular book on innovation, *The Ten Faces of Innovation*.

While Pankow is known for construction innovation using precast methods, this innovation leadership story is about building successive floors of a 35 story building, the Allure Building in Hawaii (see Figure 11). This 35 story, $158 million luxury condo building was built in Honolulu starting in late 2007. Calvin Yoshida (see Figure 12) was the Project Superintendent for this building.

![Figure 11 - Pankow's Allure Building](image1.png)  
![Figure 12 - Calvin Yoshida explains the innovation](image2.png)

Construction of a high rise building is ideally done one floor per week. This requires a consistent five-day construction cycle, with the concrete curing over the weekend, thereby eliminating overtime (something that all crew members “don’t necessarily try to avoid.”) A key to this cycle is the timely placement and removal of the support structures (formwork or *tables*) that temporarily support the concrete slabs until they are fully hardened (concrete achieves the required strength). (See Figure 13)
If each week doesn’t culminate with placing (in layman’s terms, “pouring”) concrete on Friday, you have thirty or forty people preparing to and placing concrete on Saturday (all making time and a half pay rate), and you’re jeopardizing the schedule for the next week because you don’t have enough cure time to start the next floor on Monday. Maintaining this 5-day cycle (7-day with the weekend) requires a lot of communication, coordination and collaboration, the 3 c’s.

The typical five-day cycle (simplified version) is as follows:

- **Monday:** Stress PT (post tensioning the cables) for the new slab; strip the tables from two floors down and **set those tables on the new floor** to support the concrete for the next floor to be poured in four days. When the tables are removed “reshoring” (4x4’s) are installed in their place. This makes the removal of the tables from two floors below an especially critical timing. You can’t remove them until the required concrete strength is achieved and the PT cables are stressed. If you remove them too soon the slab will deflect.
- **Tuesday:** Continue construction with “MEP Rough in”, install slab rebar and PT cables.
- **Wednesday:** Continue edge form, Set Precast
- **Thursday:** Complete Rebar and PT cables.
- **Friday:** Pour concrete floor (in morning) and shear walls and columns (in afternoon); “Friday is like a Thanksgiving dinner. All the food needs to ready and everyone is present when you sit down to eat.”
- **Weekend:** Concrete hardens and strengthens

As the Allure Building began to rise things were not going well. According to Calvin Yoshida, “When we started this building we had a difficult time achieving the five-day cycle. We were always working overtime on Wednesdays and Thursdays to make the Friday pour. This all goes back to Monday. If you don’t set tables at 10 am on Monday you’re off schedule.” It was during this period of high stress (Calvin’s not the concrete), that Yoshida noticed another building site that was using three sets of tables, with one set always on the ground. Pankow didn’t have the luxury of the third set of tables, but Yoshida devised an ingenious way to assure that a set of tables would always be ready to be set when needed without the added expense of the third set.

Yoshida decided that they could pull out the tables during the current week (Tuesday or Wednesday) and immediately “re-shore” that floor, before it is loaded with the weight of the new slab being placed on Friday. After pulling the tables they could be placed on the ground (pool deck area), cleaned and stored there until Monday when they are set at the higher level. Even
though this is an extra move for the tables, it moved them outside of the critical path and significantly reduced the work on Monday, a complex day. It also makes it possible to set tables on Monday even if the new concrete hasn’t reached its full strength, virtually assuring the maintenance of the 5-day construction cycle.

While this innovation made perfect sense to Yoshida from an overall work flow perspective, he needed to confirm that it would not create structural or safety issues. The Project Engineer and Field Engineer were brought in, and after a thorough analysis they were “on side” with Yoshida and ready to support the new process. However, other people at the site resisted. This extra move of the tables to the ground was ”added work and inefficiency.” In fact, the field superintendent, six foremen and several workers said it didn’t make sense to change the process. Many of the team members had just gone through lean process training, so the wasted effort of moving all the tables to the ground and back up again seemed to be wrong. Even the estimators in the office said that it would cost more money (but in the end it didn’t due to the elimination of overtime.) Yoshida and the engineers tried every way to convince them, but in the end they had to “pull rank” and order it done. “Finally on a Tuesday we pulled everyone together and with others on the radios and told them to strip the tables and told the crane operator to move them to the ground or else!”

This extreme move took a lot of courage and self-confidence, on the part of Yoshida. At that stage in his career, if he were wrong and there were any structural issue or increase in cost it would have been “on him”, with the consequences impacting his career. However, that was not the case. The soundness of the process was proven from structural, cost and scheduling perspectives. The five day cycle was maintained throughout the rest of the project with minor amounts of overtime, and the building was opened in 2010.

During this innovation process, Calvin Yoshida demonstrated several key attributes and competencies that are important to engineering graduates to be effective innovators in corporations:

- Open-mindedness to new concepts from any direction through associative thinking.
- Self-confident collaborator: Self-confidence combined with team playing; he assured that the other key decision-makers (field engineer and project engineer) were in agreement, and then had the confidence and courage to implement the decision
- Tenacity and determination

In addition, engineering graduates also need to realize the importance of being gracious and collaborative, especially when they are right and someone else makes a mistake. Doing so builds stronger teams within your team and professional community.

_Innovation Leadership from the Top at Ford Motor Company_

Dr. Derrick Kuzak held leadership positions in Ford’s Product Development (PD), including heading up engineering and design in Europe and the Americas before leading world-wide engineering and design for six years as Group Vice President, Global Product Development.
According to an article in the New York Times, “Mr. Kuzak’s influence as group vice president for global product development has been profound.” During his career, he and his team introduced many innovations and innovation-focused initiatives at Ford. Two aspects of his leadership of innovation “from the top” will be discussed here: building both the confidence and competence of the Ford engineering staff in areas critical to innovation, and exhibiting great tenacity in pursuit of specific innovations.

When asked how he created a culture of innovation at Ford, he answered, “When people talk about culture it’s pretty nebulous. (It’s difficult to “lead culture.”) But what you can lead and institute is operating plans and operational mechanisms. Technology was one of the elements of the operating plans and operational mechanisms that we put in place. These plans and mechanisms drive technology development and innovation throughout the organization . . . not only the entire Ford internal organization, but also through supplier partners and even university partners, like the University of Detroit Mercy.”

Kuzak defined four key elements that contributed to innovation at Ford:

1. Continually improving the skills and motivation of the engineering team and how the team works, with special focus on institutionalizing design reviews, developing business acumen, increasing understanding of customers, and applying systems engineering.
2. Making technology development and innovation fundamental elements of the Company’s business and product plans with progress measured rigorously through metrics such as the number of new technologies under development and reaching production.
3. Identifying the critical-few, customer-driven areas that are set the priorities for technology development by the Company’s engineers and those of supplier partners. For Ford these areas are fuel economy, safety, and interior comfort and convenience.
4. Establishing a defined percentage of the total engineering budget devoted to new technology development and ensuring efficiency of that spending.

A particular operational mechanism he emphasized was the design review process. Dr. Kuzak realized that overly harsh responses to an engineer’s ideas would quash engineers’ innovation and creativity. However, he also realized that design reviews need to be technically rigorous to lead to top quality products and top quality engineering performance. Kuzak stated that “The design review process is one of the most important operating mechanisms that we have as engineers. Executed properly they are a powerful practice for ensuring designs reflect the latest and best collective knowledge of the organization.

Design reviews should be led by a technical specialist, the Company’s expert in a given system or component. Indeed recognizing the importance of tech specialists and promoting them is essential to technology development. One of their roles, in fact their most important responsibility, is to lead design reviews and make them constructive learning experiences for all of the engineers. At the same time, these meetings are hard-nosed reviews ensuring the design reflects best practices and latest customer knowledge.” So, the key it to assure that the design reviews include demanding rigor and quality, but are also learning experience that build the knowledge and confidence of the engineering team.
Kuzak also emphasized the need for engineers to understand business and finance. In fact, he felt Ford and its suppliers had progressed beyond the outdated notion of a competition between “car guys” and “bean counters.” “At Ford, the starting point is that an engineer must be a business person. An engineer in today’s globally competitive market needs to have an in-depth understanding of the cost of the systems/components she is designing, where the cost stands competitively, and have plans in place to improve the cost continuously. Similarly an engineer needs to be just as focused on improving the engineering costs and investment costs needed for her system/component.” In the past, Ford partnered with MIT and the University of Detroit Mercy to develop an integrated engineering – business master’s degree, the Master of Science in Product Development, which was delivered to hundreds of Ford engineers to infuse that business acumen through the Ford engineering staff.

Kuzak also stressed the need to know the customer’s wants and needs, and felt good engineers could anticipate customers’ future interests, stating “... customer driven ... I don’t think you can emphasize that enough. ... but you also need to get ahead of customers. That’s a theme that we saw over and over again with Apple, Microsoft and Google, the need to get out ahead of customers, because customers’ don’t know what they don’t know.” Customers cannot be expected to envision how new technology can change their experiences for the better.

Derrick Kuzak’s commitment to developing the capabilities of engineers, both individually and collectively, was widely recognized throughout Ford, including the very top of Ford. When Dr. Kuzak’s retirement was announced in February 2012, Ford CEO Alan Mullaly specifically noted his commitment to engineering competence saying, “He prioritized the development of the next generation of talented, experienced product leaders who will continue to deliver for our global customers.”

Further, Kuzak assured that Ford’s plans tenaciously maintained support and focus on key technological innovations, such as EcoBoost engines, even during periods of restructuring, driving up the “refresh rate” of new technologies embodied in Ford products. This is how he told that story:

“We wanted to deliver on the best overall fuel economy, but not by sacrificing the other attributes of the vehicle, for example, acceleration capability. One of the most significant and visible technologies was EcoBoost engines. This engine technology provided an AND solution of improved fuel economy and performance, rather than a trade-off of one for the other. Eliminating or minimizing a customer trade-off should be the goal of every engineer. EcoBoost engines accomplish this balance for the customer by combining direct injection and turbocharging, known technologies, with downsizing of the engine to improve engine efficiency in a manner unique to Ford. EcoBoost engines were under development at Ford for almost twelve years starting in Europe. The early years of the work occurred in financially difficult times for Ford in Europe. Yet we kept EcoBoost engines under development because of the foresight, and frankly a fear that the need to continuously reduce the emissions from diesel engines could increase diesel costs beyond customer affordability. So we were looking for a gasoline engine alternative to deliver a similar level of efficiency as diesels. And we kept the funding even in severe financial times.
EcoBoost engines also illustrate other important elements of the technology process at Ford, beyond the tenacity demonstrated by financial commitment in difficult times. EcoBoost was aligned with one of Ford’s 3 focus area for technology, fuel economy. Its development was driven to exceed future, best-of-competition metrics in vehicle fuel economy and acceleration. And development of the new technology was aligned from its start with how it would be marketed, as exemplified by the EcoBoost name.

Finally, EcoBoost engines demonstrate the potential of systems engineering and control system expertise for new technology implementation. In fact, most of the Ford patents achieved with EcoBoost technology are associated with the control systems and algorithms of the engine and transmission. Other manufacturers have recently introduced direct engine, turbocharged gas engines, including Audi and Mazda. But to this point Ford has delivered the best combination of efficiency and torque, because of control system innovation and systems engineering application.

New technology development, like that of EcoBoost engines, was an integral element of the product development plan at Ford both from engineering and a financial perspective. Even in the development of the engineering budget a systems approach was used.

We considered Ford Product Development a system. The input to the system is the annual engineering budget, inclusive of labor, development, testing, and prototype tool costs. The output of the product development system at its most fundamental level is Ford’s global vehicle line-up. We chose as the metric to measure that output the line-up’s “refresh rate”, the percentage of the line-up that are new or significantly freshened vehicles. The freshness of an automotive Company’s vehicle line-up brings customers to its showrooms and is increasingly recognized by automotive analysts as an important indicator of the future success of an automotive Company.

This systems look enabled us to assess Ford’s PD system versus all other automotive manufacturers on 2 important measures. First, the refresh rate itself. And second, the efficiency of the PD system – its output divided by the input, in this case, the refresh rate divided by the engineering cost, specifically, the percentage of the vehicle line-up being refreshed for each engineering dollar spent. Use of this systems approach enabled the Ford PD system to drive toward and achieve world-class PD efficiency.

New technology development was managed within this system context. A target percentage of the overall engineering cost to be devoted to technology development was set. The target ranged from 8 to 10% annually, and we stayed within those boundaries even during the most difficult financial times. During the restructuring of several years ago, we made sure that a relatively high percentage of the 8 – 10 % was devoted to advanced technology delivery, at the
expense of basic research. However, with improved Company profitability, a higher percentage was given to basic research to facilitate further innovation.”

*************

Leaders like Calvin Yoshida and Derrick Kuzak understand that it takes specific actions, sometimes requiring considerable courage and tenacity, to assure that their companies create innovative products and processes.

Physical Innovation Spaces

Physical innovation spaces play a key role in innovation strategies of many of the organizations participating in this study. All of the companies that the IT team visited were aware of the importance of space on the mindset towards innovation. Two spaces that were reviewed in depth were those at the Air Force Research Laboratory (AFRL) and BASF.

Innovation Spaces at an Air Force Site

At AFRL, innovations to safeguard and/or improve the effectiveness of warfighters are paramount. Realizing that Department of Defense (DoD) regulations and systems may inhibit the speed of development and deployment of new products and capabilities, AFRL recognized the necessity of approaching some urgent needs outside of their traditional systems. In response, AFRL entered into a Partnership Intermediary Agreement with the Wright Brother’s Institute (WBI), a nonprofit organization in Dayton, Ohio. In 2008, WBI opened Tech Edge Works facility that houses the AFRL Center for Rapid Product Development and later in 2009 added the Center for UAV (Unmanned Aerial Vehicle) Exploitation. Together these two centers, in collaboration with AFRL, WBI, the Ohio Third Frontier Program, the University of Dayton Research Institute and several industry partners, provide a unique and highly effective physical innovation space complete with equipment and personnel.

Unlike many physical innovation spaces that are designed with unique architecture and aesthetically pleasing collaboration spaces, the Tech Edge Works facility is utilitarian; however, there are several aspects that make it unique.

- “Outside the Fence”: A primary success factor of the facility is that it is located “outside the fence” of AFRL at Wright-Patterson Air Force Base, Ohio. Since the 9/11 terrorist attacks, access to DoD facilities by outside personnel is challenging and can inhibit the access and collaboration necessary for cutting-edge innovation.
- Equipment: Tech Edge Works has an impressive array of equipment from high-speed computer modeling systems and software to 3D printers and other rapid prototyping equipment to low volume production equipment. Some personnel refer to the facility as their “Monster Garage,” referencing the popular Discovery Channel television show.
- Highly Trained Personnel: The equipment is available for use by sufficiently experienced collaborators, and Tech Edge Works also has highly experienced staff available to assist innovation teams with intricate operations and/or to help the teams execute more rapidly.
In addition to the physical innovation space, AFRL has other innovation facilities that facilitate virtual collaboration with a broad array of sources around the world through open innovation resources. The Air Force is part of several consortiums including Innocentive ©, Yet2 © and Inno360. For example, Inno360 allows AFRL to partner and build relationships with innovators, and to catalog the experts in different areas of expertise. The value in such open innovation environments was described by the Deputy - AFRL Innovation and Rapid Reaction Team, as follows, “We used to keep working with the same companies and after a while they became “native” . . . this opens up sources that would never think of working on a defense problem.”

BASF’s Innovation Space

Another compelling physical innovation space visited was at BASF’s Wyandotte, MI facility with a focus on engineering plastics. Innovation at this facility comes in three forms: (1) new materials, (2) new applications, and (3) new process technologies. The BASF innovation center consists of two adjacent areas: one with a large open workspace, primarily used as a workshop for product teardown, and the other with a team meeting/ideation space. These spaces, shown in Figures 14 and 15, emerged from a shift in BASF processes from rigid processes to a more flexible, customer-focused environment. Both spaces are modern and colorful, thus invoking a feeling of “what happens here is not business as usual”. As can be seen in Figure 14, the walls in both spaces have colorful display areas where numerous successful BASF innovations and products that are targeted for innovation serve as stimulus for generating new ideas. Each innovation is accompanied by a description of the project and its results.

Figure 14 - BASF Innovation Center Wall Hangings

Frequently the BASF teams work directly with their customers in the innovation center. The meeting space, as shown in Figure 15, is a flexible space that allows for standing or seated meetings, has a large open area (not shown), ample white boards, and has past successful projects on the wall for inspiration (not shown). Also, the layout facilitates collaboration and creativity with its open and flexible design. In addition, moving the innovation teams out of their home environment allows them to leave their normal duties behind and to collaborate on cross-functional teams while in the innovation space.
One of the primary uses of the open space is for “teardowns” where BASF teams look for new opportunities for using plastic. On the surface this may not sound like true innovation, but often these new opportunities allow for new design opportunities for customers because of the flexibility and/or the low weight of plastic compared to metal. Many of these also provide sustainability improvements through “light-weighting.” In one example, a new car was brought in and was completely disassembled piece-by-piece generating many new opportunities because of the flexibility of plastic molding and its lighter weight than metal. One such opportunity was to make internal combustion engine oil pans from plastics specially molded to provide exceptional strength and lighter weight. Of course, convincing veteran automotive design engineers to move from metal to plastic has proven challenging even in light of the fact that plastic oil pans have already proven successful on several cars and trucks.

Figure 15 - BASF Innovation Space Meeting Area

Although innovation is clearly more about process than physical innovation spaces, the authors agree that such spaces provide a stimulating environment conducive to creative thought and innovation. An atypical space set aside solely for innovation activities, that is separate from one’s daily work activities may contribute to the mindset necessary to conceive of new and different ways of doing things - which is at the heart of being innovative.

The Voice of Corporate Innovation Leaders: Recommended Innovation Competencies

In addition to observing and discussing innovation methods, culture, leadership and spaces, the innovation study team asked for recommendations of innovation-related objectives of engineering education. When asked, “What behaviors and competencies do you want in your new engineers that would make them more effective innovators and intrapreneurs in your company?” over 100 corporate leaders said,

_We want engineers who are confident, competent, open minded engineers who work effectively on teams that employ experimentation, analysis and innovation to create and “sell” products that are truly responsive to customers around the globe._

Actually, no one leader said precisely that. This is what you get if you “boil down” 168 recommendations during intensive visits to an Air Force innovation center and nine major corporations from a wide variety of industries (automotive, aerospace, building, chemical/materials, communication, food, information and medical). While this conversation
was not as structured as a formal survey instrument/process, the specific responses and dialog reveal a rich array of attributes that include not only competencies, but personal behaviors, values and characteristics that are deemed by innovation leaders to be necessary to becoming an innovative corporate engineer.

Almost all of these recommendations can be grouped into six broad competency areas created based simply by the number of mentions of them in responses:

1. Technical competence
2. Innovation
   a. Anthropologist
   b. Cross-pollinator
   c. Experimenter
3. Breadth (“T-shaped”)  
4. Communication/value proposition
5. Teamwork
6. Confidence

![Figure 16 - Number of Recommendations in Broad Competency Areas](image)

The remainder of this section provides more detail regarding recommendations in each of these innovation competency areas.

**Competency Area 1 - Technical Competence**

Technical competence was mentioned on all I-ship visits as an underpinning of technological innovation. As expected, the specific technologies varied by industry, such as software competencies at IBM and Comcast, and chemical/materials at BASF and DuPont.

Several companies noted the importance of systems engineering. At the Lockheed Martin *Skunk Works* they linked this to deep understanding of the whole product [*being an “airplane guy” or “car guy”*] (apologies for any implicit gender insensitivity), and the broad *T-shaped person* that will be discussed later. Ford’s Derrick Kuzak, Group Vice President for Global Product
Development, was very clear on the priority of systems engineering when he said, “I can’t think of anything that’s more important than to be a system thinker.”

Some companies also emphasized the related priority of optimizing the whole, rather than the component, using interesting metaphors to clarify the balance of focus on discipline/component versus the system. Lockheed Martin leaders recommended that engineers first need to “apply an axe to chop the problem down to its essence, and resist immediately using a drill to search for the nugget of innovation.” IBM also discussed the need to focus on the right problem and the value proposition before creating the product. Leaders at Ford cautioned against excessive allegiance to one’s sub-discipline, as they sometimes need to “keep the composites engineer from using composites for all “light-weighting” challenges.”

**Competency Area 2 - Innovation and Three “Faces” of Innovation**

All of the companies recommended broad competencies related to creativity/ideation, sometimes putting their special “spin” or focus on their recommendations. In addition, many of them discussed behaviors and competencies that are closely related to three personas or *faces of innovation*: the anthropologist, the cross pollinator and the experimenter. A leader from the Air Force explicitly recommended those three faces as described in *The Ten Faces of Innovation* as outcomes for engineering education. The broad creativity/ideation competencies will be discussed first, and then the three recommended faces.

A number of companies recommended that engineers be able to generate ideas, using a variety of phrases summarized in Table 2.

<table>
<thead>
<tr>
<th>Source</th>
<th>Recommended Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Force</td>
<td>Intellectual curiosity</td>
</tr>
<tr>
<td>BASF</td>
<td>Inquisitive; brainstorming</td>
</tr>
<tr>
<td>Campbell Soup</td>
<td>Curiosity – proactively curious</td>
</tr>
<tr>
<td>Comcast</td>
<td>Design; many design courses (like IDEO)</td>
</tr>
<tr>
<td>DuPont</td>
<td>Design/innovation: Can come up with strong IP</td>
</tr>
<tr>
<td>Ford</td>
<td>Innovative</td>
</tr>
<tr>
<td>IBM</td>
<td>Creative; able to come up with ideas; architectural/innovation skills; experienced in innovation</td>
</tr>
<tr>
<td>IMDS</td>
<td>We want the most innovative engineers</td>
</tr>
<tr>
<td>Lockheed Martin</td>
<td>Product focused: innovation over invention; creating assumptions to start ambiguous problems; identifying alternative approaches</td>
</tr>
</tbody>
</table>
In addition to these broad capabilities, IBM and IMDS also recommended knowledge of the patenting process, both as an ideation method (patent searching) and as a means to protect ideas.

**Competency Area 2a - Anthropologist**

Almost all companies emphasized that engineering graduates who are good intrapreneurs have capabilities and behaviors commonly assumed of an anthropologist, especially those related to understanding the customer and the world.

Ford and IBM both emphasized listening and empathy, behaviors that are seldom on the list of target outcomes of engineering education programs. IBM expanded on the process of gaining understanding of the customer: “observe and listen and document and clarify with customer first; determining what is driving the client's mission?” They also had the interesting observation about the negative impacts of students’ emphasis on social networking, “Social networking is focusing on me, me, me, but the job of engineers is to focus on the needs of others.” They also bemoaned the concomitant lack of conversational skills that are so valuable in seeking out customers’ wants and needs. IBM and Ford also see value in the engineer with a global customer perspective, recommending that the engineering graduate be able to “adapt to new cultures” (IBM) or be “globally oriented” (Ford).

Finally, several companies discussed ways in which engineers should think or see their place in the world. For example, Campbell Soup, Comcast and Ford recommended critical thinking and reasoning as capabilities, areas that are important to learning from observations of customers. The Air Force values the attribute of **connectedness** as described by Gallup: “Connectedness implies certain responsibilities. If we are all part of a larger picture, then we must not harm others because we will be harming ourselves. We must not exploit because we will be exploiting ourselves. Your awareness of these responsibilities creates your value system. You are considerate, caring, and accepting. Certain of the unity of humankind, you are a bridge builder for people of different cultures. Sensitive to the invisible hand, you can give others comfort that there is a purpose beyond our humdrum lives.”

The medical device innovator IMDS even employs a development engineer profile developed by Gallup to evaluate and hire engineers. (See the section below on confidence for discussion of related values and attributes.)

**Competency Area 2b - Cross-pollinator**

Six different companies recommended that engineers be adept as bringing ideas from one product domain or industry to another. This was expressed in a variety of ways: “Look anywhere for solution” (Air Force), and “Inquisitive, open minded” (Lockheed Martin). IBM leaders provided several perspectives such as “open to seeing potential ideas in other areas,” “not reinventing the wheel or the standards,” “review of existing patents in the product area would support this” and “skills to interface with industry experts.” Pankow recommended a specific behavior that reflects the same attribute, “people need to pick up the phone and call” (whatever source there is for understanding a market, a system, a product, a technology).
Competency Area 2c - Experimenter

While the Air Force leader explicitly recommended that an engineer be a capable experimenter as described in The Ten Faces of Innovation by Kelley\textsuperscript{7}, many others recommended other aspects of Kelley’s experimenter, or other attributes that are closely aligned. For example, DuPont recommended strong experimental skills, while BASF recommended learning from failure and Lockheed Martin recommended that engineers “accept a failure and move on.”

DuPont, Ford and Lockheed Martin emphasized the need for prototyping and modeling capabilities in engineers. DuPont emphasized the ability to create both physical and virtual prototypes through the following process: Concept $\rightarrow$ Model $\rightarrow$ Experimental Validation. (See the innovation story above related to the creation of a new body armor system at DuPont.) This creation of virtual models can allow virtual testing to create new and better concepts at the early stages of this process. Such sophisticated modeling requires special computational and data skills in engineers, and well as deep understanding of the product, process and material phenomena at the level of first principles. Lockheed Martin leaders simply stated that they want engineers who can “model, design, build and test products.” Ford emphasized the use of “experimental prototyping” such as that employed at IDEO, for exploring a design space, rather than proving out a design concept or product (Brown)\textsuperscript{18}. This most often involves the use of such things as PVC pipes, Styrofoam and duct tape, as opposed to metal and the machine shop.

Some of the same values of Ford’s use of experimental prototyping are at the root of cautionary statements that engineers should not rely too heavily on extensive analysis and modeling, especially early in the design process. Lockheed Martin leaders recommend that engineering graduates be “able to apply different methods to solve a problem: back of envelope, historic data, complex equations, experimental methods, etc., but you don’t need CFD (computational fluid dynamics) for everything.” Similarly, Pankow leaders said that engineers need to realize that “because we can do more things, we don’t need to do more things,” such as doing more analysis than is necessary.

Finally, several leaders recognized that deep understanding of the product, and real systems in general, was extremely valuable in driving both design and experimentation. Lockheed Martin said “The more real world hands on knowledge they can get the better (airplane engineers should fly and repair airplanes).” Pankow recommended “field experience” in construction (co-op, internships); this lets them understand what they are designing.” Interestingly, DuPont wants “car guys” (and “car girls”), stating that they are looking for engineers who “understand real systems - people who work on their own car.”

Competency Area 3 – Breadth

Six companies emphasized the need for the “T-shaped” person, with both depth in his/her technical area, but also “right brain” capabilities, such as art. This is also emphasized in many popular books on innovation (Kelley\textsuperscript{17}, Brown\textsuperscript{18}, Pink\textsuperscript{33}). In fact, BASF, IBM and Ford explicitly used the term “T-shaped” in describing the idea engineering graduate. An IBM leader clarified what this means, “deep in one area but can converse with others in other disciplines and with management and other functions, and can impact horizontally as well as vertically.” At Ford they are concerned that “You need to fight the ‘we tried that a long time before’ mindset. These type of people are often very deep in a narrow area; the preferred person would be more T-shaped, with depth but complementary breadth.” A leader at Lockheed Martin put it in terms
clear to the aerospace industry, “(Engineers need) ‘multi-disciplinary knowledge. They need to read more than just Aviation Week. If you do the ‘front end’ innovation, you can’t be an exclusive “airplane” guy. You need to be broader.” Finally, both BASF and IMDS both valued the ability of engineers to manually articulate concepts, recommending sketching or “napkin design.” As one might expect, other forms of communication skills were also recommended.

Competency Area 4 – Communication and Value Proposition

Every corporate partner in this study strongly recommended good communication skills, including both speaking and writing, and almost all added the ability to develop and articulate a value proposition in compelling, persuasive ways. DuPont prescribed several specifics, recommending “How to propose; how to report; how to write; how to sell; how to make a presentation.”

Many corporate leaders elaborated on the need to be able to “sell” the concept or product to the customer or client. Lockheed Martin emphasized the need to clearly translate the technology to the impact on the buyer by “articulating what the technology will mean to customers; when presenting your concept or product to the customer, stick to ‘small words and simple concepts.’” Leaders at IBM broke down communication and selling skills into several components including “document ‘use cases, articulate technical skills to client, show relevance to client.” At Campbell Soup they felt the engineer needs to “see how the parts fit together, including the market and the consumer.”

Several companies also emphasized that “business acumen” is needed to develop a value proposition, and, indeed, to develop a product that provides value. They recommended such things as “how to cost something out” (DuPont), “engineers who can bridge the gap to the business side” (IMDS), or “dealing with a customer from a business standpoint” (Lockheed Martin).

Pankow’s leaders are concerned that students understand that communication should be limited to what is necessary to communicate, stating that engineers need to “realize that just because it’s easy to keep everybody in the loop, you don’t need to do so. It can create an unnecessarily large flow of information that people don’t need (or don’t need to review).” Finally, leaders at Pankow cautioned that students need to learn to follow up on electronic communications to confirm that the recipient has reviewed it and understands it; “students think sending the email without follow up or conversation is enough, but it’s not.” The dangers of over-reliance on emails (and by implication, on text messaging) were amplified by Tom Kelley of IDEO:

“Street-savvy Collaborators know never to confuse email with genuine human collaboration. I’m constantly dumbfounded at how many people send out emails when what they really need to do is make a far more efficient two-minute phone call. That’s maybe the most important suggestion. . . . Make time for lots of little and long conversations. Don’t say something in an e-mail that you wouldn’t say in person. Avoid ambiguous e-mails that might possibly be misinterpreted by someone who’s had a bad day. And if possible, never initiate contact through an e-mail.” (Kelley, p. 133)
Competency Area 5 - Teamwork

Like communication and selling skills, all corporate partners emphasized the need for engineering graduates to effectively work on teams and to have the requisite interpersonal skills to do so.

Several companies emphasized the ability to work with and accept all people:

- “value people with different skills and perspectives” (BASF)
- “respect for all people, especially the people making the products” (IMDS)
- “understand people, especially different generations” (Pankow)
- “understand the person’s personality and ability to interact with team members” (BASF)
- “ability to understand people; how to deal with people” (Comcast)
- “collaborative teamwork in cross generational groups; understand the generational issues of team members” (Campbell Soup)

Other companies recommended the development of collaboration skills, such as “Good mediation/negotiation skills (esp. with suppliers on shared ideas).” (Ford) At the Lockheed Martin Skunk Works they summed up their valuation of unselfish collaboration by saying “We like to hire students who helped others on design teams.”

One of the leaders at Pankow recommended a related attribute that is very difficult for many personalities to accept; “Being right isn’t the most important thing for building long term collaboration, cooperation and compromise. It is critical to treat people with respect and to understand and appreciate what their requirements and needs are.”

Finally, Lockheed Martin mentioned that they want engineers who are willing to take on different roles on teams at different times. “They need the ability to both lead and to follow/contribute.”

Competency Area 6 - Confidence

The last, and possibly most important, area that was recommended and discussed with the i-ship corporate partners is confidence. All but one company recommended that innovative engineering graduates have high levels of confidence and/or attributes and behaviors that depend directly on such confidence. It is not enough that an innovative engineer by competent, he/she must also have the confidence needed to

- question the status quo enough to consider disruptive solutions
- take risks and learn from failures
- be a self-starting seeker of opportunities
- have the pride and motivation to make a big difference
- have the integrity to tell the truth, even when its bad news
- live with and function well with ambiguity
All of these capabilities were suggested as important to being an innovative engineer and intrapreneur in corporations, and all depend to a significant degree on one’s self-confidence. In fact, without self-confidence, it is difficult for a person to do any of these things.

The following are some of the specific ways that different corporate partners recommended the capabilities and behaviors that require high levels of confidence:

Table 3 - Recommended Capabilities Related to Confidence

<table>
<thead>
<tr>
<th>Recommended Capability</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>self-starting; ask what to do; proactive solution finders</td>
<td>Pankow</td>
</tr>
<tr>
<td>self-directed</td>
<td>Air Force</td>
</tr>
<tr>
<td>eagerness to jump in and have the confidence to “figure it out” – be able to take risk</td>
<td>IBM</td>
</tr>
<tr>
<td>self-confident; low fear of failure</td>
<td>BASF</td>
</tr>
<tr>
<td>not afraid to step up and take responsibilities</td>
<td>Lockheed Martin</td>
</tr>
<tr>
<td>willing to be very wrong</td>
<td>Lockheed Martin</td>
</tr>
<tr>
<td>confidence to question the status quo and try new things</td>
<td>DuPont</td>
</tr>
<tr>
<td>people who just challenge things (they want to know why we’re doing something in a certain way)</td>
<td>Pankow</td>
</tr>
<tr>
<td>disruptive</td>
<td>IBM</td>
</tr>
<tr>
<td>wants to make a big difference</td>
<td>BASF</td>
</tr>
<tr>
<td>moving from a sense of entitlement to a strong work ethic in order to be able to make a difference; personal pride; ability to “bring it in through actual doing”; ability to make it happen.</td>
<td>Pankow</td>
</tr>
<tr>
<td>integrity (telling the truth, not hiding issues, escalating issues that need attention)</td>
<td>Ford</td>
</tr>
<tr>
<td>continuum principle: need to live with ambiguity and willingness to not have everything done the way you want them.</td>
<td>Ford</td>
</tr>
<tr>
<td>willing to work for nothing (passion for one’s work and its impact)</td>
<td>Lockheed Martin</td>
</tr>
<tr>
<td>Accept failure</td>
<td>Campbell Soup</td>
</tr>
</tbody>
</table>

While there are all of these positive impacts of a high level of self-confidence, are there any potential negative behaviors or performance effects of having high levels of self-confidence? One concern was voiced by Ford. If self-confidence becomes over-confidence, the engineer may lose the ability to accept criticism that improves the design or product. This behavior may occur in design team meetings when engineers, in their zeal to promote and sell their innovation, blind themselves to valid concerns or valuable modifications regarding the concept or product that
could make it even better. For recent engineering graduates, who are trying to find or establish their place in the organization, their reaction to critiques of their design may be derived from a defensiveness, especially if they think that others’ concerns might reflect any lack of confidence (real or perceived) by more senior engineers or managers. All of this points to a key linkage between confidence and mastery of the capabilities that are central to the engineering profession. If one’s confidence is based on true mastery, then it rises to the level that questions and critiques regarding your idea or design are seen as a valuable contribution towards excellence in the outcome. It becomes a contribution toward the success of the innovation, rather than a personal challenge to one’s capability. It is this balance of confidence and openness (to examination of the person’s concepts or designs) that is ideal for the most effective innovators.

This balance can be developed by engineering educators as they engage students in the review of their design projects, and maintained by effective engineering leaders as they run the design reviews of their companies. If engineering professors provide only severe criticism of students’ design projects, they risk destruction of the students’ self-confidence. If they only encourage without feedback on a concepts shortcomings, then a false sense of self-confidence without mastery may result. However, if professors couch their comments in the context of aiding the student in achieving mastery of engineering, the student’s motive may change from seeking praise and high grades (extrinsic) to seeking mastery (intrinsic) . . . a far more effective motivator. (*Drive*, Daniel Pink)21

Derrick Kuzak, Group Vice President for Global Product Development at Ford Motor Company, understood the need for a balance of encouragement and criticism that must be applied during Ford’s design reviews. He described the importance of design reviews and their balance of mastery and confidence as follows:

> The design review process is one of the most important operating mechanisms that we have in the engineering community. Design reviews are led by technical specialist. One of their jobs, in fact their most important job, is to lead design reviews and make it a constructive learning experience for all of the engineers. These meetings are hard-nosed design reviews . . ., often run over digital systems with people from around the world.

Leaders at Lockheed Martin and Pankow also recognized that need to balance confidence with openness and respect for input from others. The leaders at the Skunk Works © said that young engineers need to “know when you’re in over your head (and who to go to for help).” At Pankow there was a recognition that over confidence could inhibit effective teamwork; “The hard chargers in the field often rise to the top, but then (when they return to the office to lead project teams) are too harsh with people under them. “

Finally, while there were direct references to Kelley’s *Ten Faces of Innovation*, the team also found that the array of recommendations and observations were consistent with another popular book on innovation, *The Innovators DNA*.19 There were multiple companies that recommended and/or demonstrated all “five skills of disruptive innovators” described in that book:

1. “Associative skills (Pankow, Campbell, Comcast)
2. Questioning (IBM, Air Force, Lockheed Martin, Campbell, IMDS, BASF )
3. Observing (IBM, Campbell)
4. Networking (all ten)
5. Experimenting (DuPont, BASF, Lockheed Martin, Campbell, Air Force, IMDS, Comcast).

Next phase of this Intrapreneurship Study

The visits to ten major corporations spanning corporate America’s geographic and industrial landscape yielded extensive new insights regarding aspects of culture, leadership, process and workspace that support innovation and intrapreneurship in corporations. The implications of these four dimensions, combined with the specific recommendations presented in the “Voice of Corporate Innovation Leaders” section above, begin to define the ultimate goal of this study: outcomes for engineering graduates who will be uniquely effective as innovators in corporations.

The next goal of the I-ship Study Team from Baylor, Dayton, Detroit Mercy and Villanova is to chart a route to that destination that includes specific learning outcomes and curricular and co-curricular programs, courses, projects and other activities for that educate a new generation of more innovative, intrapreneurial engineers. 

工程师们要有信心，有能力，有开放的心态，能够有效地在团队中采用实验、分析和创新来创造和“销售”真正响应全球客户的产品。

REFERENCES


4. Duval-Coueti, Nathalie and Dyrenfurth, Michael J., “Teaching Students to be Technology Innovators: Examining Approaches and Identifying Competencies”, Proceedings 2012 ASEE Annual Conference.


17. Kelley, Tom, “The Ten Faces of Innovation” (Doubleday), 2005


22. Quast, Lisa, “The Skills Necessary to be a Successful ‘Intrapreneur’ (Corporate Entrepreneur)”, Forbes Magazine, June 20, 2011


