- Minutes -
Engineering College Council Meeting
October 30, 2015
Ithaca, NY

Members Present: Nadine Aubry, Jim Becker, Najib Canaan, Lance Collins, Bob Cowie, Frank DeCosta, Michael Even, Sarah Fischell, Greg Galvin, Virginia Giddings, Ken Goldman, Michael Goguen, Frank Huband, Andrea Ippolito, Michele Kaliski, Jonathan Ludwig, Ivan Lustig, James McCormick, Howard Morgan, Richard Ong, Jim Ricotta, Bob Shaw, Daniel Simpkins, Elissa Sterry, Duane Stiller, Sherri Stuewer, Joseph Thanhauser, Craig Wheeler, Eric Young, Todd Zion

Emeriti Present: Dick Aubrecht, Jay Carter

The meeting presentations and materials can be found at:
https://confluence.cornell.edu/display/ECC/2015+Fall+ECC+Meeting

Username: eccmeeting@gmail.com
Password: eccmeeting#

Welcome and Introductions

Duane Stiller, ECC Chair, welcomed the Council to the Fall '15 ECC Meeting. Lance Collins, Dean of Engineering, announced that the focus of the meeting would be advanced materials, and entrepreneurship at the graduate level. He also welcomed the new members to the Council: Nadine Aubry, Northeastern University; Frank DeCosta, Finnegan, LLP; Andrea Ippolito, Department of Veterans Affairs; Michele Kaliski, Public Servant; Jonathan Ludwig, Barclays Capital; Richard Ong, RRJ Group; and Eric Young, Canaan Partners.

Advanced Materials

Moderated by Emmanuel Giannelis, Walter R. Read Professor of Engineering, Materials Science and Engineering; Associate Dean, Research & Graduate Studies

Emmanuel Giannelis opened the Advanced Materials session indicating that advanced materials is one of the College's strategic initiatives and is also a field that has been traditionally strong in the College and in the University since its inception in the early 60's.

Craig Fennie, Associate Professor, Applied and Engineering Physics, gave a presentation on his vision of how we can do materials research at Cornell. Fennie works in computational and theoretical materials physics. He and his research group use theory to study new, structurally and chemically complex solids and nanostructures. His innovative design of new materials that have never been created in the laboratory dramatically reduces the time to optimize materials for specific applications.

Fennie indicated that materials research today involves the successful integration of the challenges posed by "Obama and Feynman". He emphasized that we need "materials-by-design" research to close the loop between theory and experiment, science and engineering. He noted that the DOE convened a panel of experts to discuss what research we should do in the next 20-30 years. They compiled a report outlining the grand challenges for science and the imagination (3 of the 5 grand challenges involved materials by design at the atomic level). This new era of science involves the design, discovery, and synthesization of new materials and molecular assemblies at levels of electrons and atoms. He added that advanced materials research will take the collective effort of condensed matter and materials physicists, chemists, biologists, molecular engineers, and those skilled in applied mathematics and computer science and electrical engineering and others. In 2011, Obama commissioned a report from the White House known as the Materials Genome Initiative to discover, develop, manufacture, and deploy advanced materials at least twice as fast as possible today, at a fraction of the cost. He indicated that we need new materials to have a competitive edge in society.

Fennie pointed out that on Feynman's last blackboard he wrote: "What I cannot create, I do not understand". He noted that materials design and discoveries are often the result of happy accidents. These happy accidents take us from one point in our science and engineering knowledge to huge leaps into the future. However, he added, we can and should be doing more research. The usual approach is synthesize, characterize, compare with a targeted metric (and occasionally with theory), and describe microscopically (i.e., theory). Fennie indicated that we just don't break one rule, we break all the rules in what you think about materials research. On the Feynman side, the goal is to improve the understanding of some strange behavior. Once we have the microscopic description and understand experiments and known materials, the challenge begins. He explained the Obama loop is to create useful materials, whereas the Feynman loop is to study fundamental interactions. Feynman was trying to tell us to close this loop between theory and synthesization. Our vision for materials research is closing the loop between theory and experiment, science and engineering.

Fennie noted that innovative materials research is possible at Cornell due to our facilities which are incomparable to anywhere else in the world. We have CCMR, CHESS, and STEM facilities, however, we don't have a facility on campus where we can hire bright, young faculty to go and win NSF-MRI grants to enhance our facilities. He mentioned that it takes students who are experts in their field to make this happen and that it also take former students (such as the ECC members) to make this work.

Fennie concluded that Advanced Materials research takes patience and a village to carry out. There is a critical need to expand theory facilities in engineering at Cornell.

Grace Xing, Professor, with joint appointments in Electrical and Computer Engineering and Materials Science, gave a presentation on her research on Advanced Materials. Her research focuses mainly on four areas, supported by DOD, NSF, NRI and ND: 1) GaN (gallium nitride) based devices; 2) nanowire enabled devices; 3) graphene physics and devices; 4) tunneling field effect transistors for high efficiency logic electronics.

Making tiny switches do enormous jobs in a more efficient way than current technology allows is one of the goals of Xing's research team. Her group – which includes her husband, Debdeep Jena, Professor of Electrical and Computer Engineering at Cornell – have created GaN power diodes capable of serving as the building blocks for future GaN power switches. Her research group built a GaN power-switching device, approximately one-fifth the width of a human hair, which could support 2,000 volts of electricity. With silicon-based semiconductors rapidly approaching their performance limits in electronics, GaN is seen as the next generation in power control and conversion. Applications span nearly all electronics products and electricity distribution infrastructure. Xing noted that her team's research gives hope for the future of GaN power diodes. The team's work is supported in part by the U.S. Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) "SWITCHES" program. SWITCHES stands for Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems. She pointed out that her team, in collaboration with their industrial partners, has established an integrated plan to develop three terminal GaN power transistors, package them, and insert them into circuits and products. Xing also indicated that they are also looking at the CPU's of the next generation of computers. Today's computers are too hot and produce too much energy. She added that her research group has proposed a couple of devices to improve this situation.

Rob Shepherd, Assistant Professor, Mechanical and Aerospace Engineering, gave a presentation on Advanced Materials for the Additive Manufacturing of Machines, Organic Robotics Laboratory (ORL). He indicated that his research focuses on using synthetic adaptation of natural physiology to improve machine function and autonomy encompassing three main areas: bioinspired robotics, soft sensors and displays, and advanced manufacturing, using soft materials, mechanical design, and novel fabrication methods to replicate sensory organs such as dermal papillae, replicate organs that rely on actuation such as the heart, and to power soft actuators and robots. Through his research Shepherd has developed walking robots, soft electronic skins that sense touch and shape in response to mechanical stimuli, and biomimetic actuators that mimic the function and movements of natural organs, such as the heart. He noted that this was developed by coupling bio-inspired design with advanced fabrication methods (such as 3D printing of synthetic biomedical machines, soft lithography, and rotational molding). Shepherd is also developing electronic sensors and visual display solely from soft materials (elastomers, hydrogel, embedded hard components) for soft robotics, prosthetics, and wearable devices. In addition, he is developing advanced methods based on direct ink writing, digital mask projection stereolithography, conformal lithography, and rotational molding to fabricate soft robots, wearable devices, displays, and sensors.

Panel Discussion with faculty regarding the interface and future of advanced materials and nanotechnology

Moderated by Emmanuel Giannelis, Walter R. Read Professor of Engineering, Materials Science and Engineering; Associate Dean, Research & Graduate Studies

Debdeep Jena, Professor, Electrical and Computer Engineering, discussed his research on semiconductor devices which he has been developing in collaboration with Prof. Grace Xing's research group. He noted that in the last 10 years there has been a revolution in semiconductors and that the primary goal of his research is to make new devices to exploit, and understand new physics. This research includes the study of:

- the performance limits of ultrahigh speed GaN transistors,
- wide bandgap semiconductor transistors for power electronics,
- all-electronic THz sources,
- ultra-low power sub-Boltzmann switching transistors by tunneling and other correlated mechanisms,
- deep-UV LEDs and lasers approaching 200 nm using quantum dots, and
- extreme-electron concentration devices in oxides.

Jena indicated that they are learning how to make these devices conductive. These devices can emit light which can talk directly to molecules and can build memory and logic into these devices. Consequently, these devices can diagnose and do theuropeutics in remote areas using solar energy. He noted that this research path requires that they explore new materials, which grow by themselves using Molecular BeamEpitaxy (MBE), or work very closely with groups that do. Jena pointed out that the materials families they are investigating for these devices are: Nitride Semiconductors, Graphene and 2D Crystals, and Oxide Semiconductors. These devices also require a deep theoretical understanding of electron transport, electron-phonon interactions, light-matter interactions, geometric and topological aspects of condensed matter physics, and correlated electron physics. He noted that they do most of the theory and modeling themselves, and work closely with theoreticians when necessary. He added that superconductors and semiconductors are based on information coded off of macro molecules. Jena is interested in taking these advances and integrating these into macroelectronics. He concluded that we need to harness this knowledge.

David Muller, Professor, Applied and Engineering Physics, gave a presentation on his research which is focused on understanding the behavior of materials and devices at the atomic scale, with an emphasis on renewable energy applications.
He noted that the ability to design materials at the atomic scale has been known since 2000. Muller indicated that by using extremely powerful electron microscopes, placed in specially-designed and environmentally isolated rooms, they are able to explore the

chemistry, electronic structure and bonding inside objects as diverse as transistors, fuel cells, and two-dimensional superconductors. All of these systems are made up of different materials, and where they join at the atomic scale, the boundary conditions on the quantum mechanical wave functions force very different behavior from what might be expected of the bulk materials. Muller indicated that the boundaries they are searching for involve new and unexpected phases and physics. The impact of this research on large and small devices could be significant.

Uli Wiesner, Spencer T. Olin Professor of Engineering, Materials Science and Engineering, discussed his research which involves the interface between polymer science and solid-state chemistry. The goal of his research is to combine knowledge about the self-assembly of soft materials with the functionality of solid-state materials to generate novel hierarchical and multifunctional hybrid materials.

Wiesner noted that over the last ten years, to understand structure formation principles, silica-based hybrids from block copolymer mesophases have been studied extensively. He added that one of the main working principles involves utilizing the thermodynamics of amphiphilic block copolymers. Wiesner noted that these principles have been extended to other oxides as well as to non-oxide ceramics. He added that synthesis results in mesostructured hybrid materials with structure control down to the nanometer length scale that upon thermal processing can subsequently be converted into purely ceramic materials with preserved structure. The final materials have a broad range of potential applications.

Wiesner's research also focuses on a novel class of fluorescent core-shell silica nanoparticles, referred to as C-dots, with potential applications, such as fluorescent labels in biolabeling and bioimaging. He explained that water-soluble C- dots encapsulate multiple organic fluorophores into a solid-state silica environment, which improve their photophysical properties as compared to the free dye in water. As a result of their optical property profiles they constitute an attractive alternative to existing materials platforms for applications in information technologies and the life sciences requiring bright fluorescent probes. Wiesner noted that he just received $10 million from the NIH for his C-dots research. These very small particles will allow surgeons to visualize cancer cells during surgery so that they accurately determine which cells need to be surgically removed. Until now, we did not have the nanoparticles to give the surgeon clues.

Question: is there a difference in the theory side, in the realization?
Wiesner: your body integrates everything in the macro scale by your body. But to integrate this into all these length and time scales is very complex. That integration is a real challenge.

Question: Do you think that you need live research and how much can be simulated with respect to these concepts?
Jena: Sometimes simulation goes far ahead of research. It's always been synergistic.

Muller: we know what the equations are, but we don't know how to solve them.
Fennie: Theorists have ideas and then quantum calculations, but during the experimental part you discover much more than you ever imagined and they're many phenomenal properties that you can discover. Experimentalists have to narrow down these properties.

Question: Can you push it even further? Do you have enough exposure to people on the computational side to help you?
Wiesner: It would be very exciting to use CS to improve research.
Jena: Computation power at Intel can solve problems.

Question: What does the College need in the next 20 years?
Muller: The College needs to roll out a hiring initiative on the future of nanoscience in the next 10-20 years. We'd like to build sensoring devices that can fit in a rain drop. We need to find ways to store energy, and communicate, and build the circuitry to make this work. We need more people able to make more materials. We have some big gaps. The number of people on campus that work with materials is quite small in order for us to get centers, etc.
Wiesner: 17 years ago we had CHESS, CNF and CCMR, and no other centers have been added since then. The issues we're facing as a society have become more and more complex and can't be solved by any individual field. We have to be more proactive in getting faculty together who are interested in cancer research. Currently, we don't have a platform to bring these people together. He added that we need the Council's help in letting the University know that we need a platform to solve this complex situation.

Question: is this initiative being done anywhere else where it's working?
Wiesner: The administration needs to know that faculty come to Cornell for the intellectual challenges that are available. The smartest people are working on initiatives that will affect us in the next 10-20 years. The Council, as people in industry, can assist us on getting on that platform. It's not the buildings, but the intellectual discourse that they we have. Stanford and MIT get a lot of press. We're not active enough about getting the word out about what we do. The Council can help us promote the intellectual environment we want to create in the future. If you're a young faculty member you're trying to orient yourself. When he started in academia he was pulled towards the Life Sciences. The seeds are generated very early. Platforms such as the Atkinson's Center provide the opportunity for people from very different centers to collaborate.

Comment regarding improving the reputation of the College.
We should provide our UG students with research opportunities since they are going to be at the forefront of industry in 4 years and will need to have these tools in hand. We should target having at least 50% of our students in the lab. We need to get these research concepts into the classroom.
Muller: UG research is required for admission to PhD programs. If we want more UG students in labs, we need more Ph.D. students.

Question: having the time to do research as an UG is limited. Are there ways of integrating research into the curriculum?
Muller: the CCMR Materials Science center has helped with this. It has brought people together from across the university to solve problems. This center brings students for the UG and Graduate levels. Students also learn to talk to people outside of the center.
Wiesner: Offering UG research as an elective for credit would be good, that way it's not an add-on to their workload. You can't teach creativity. We need to create an environment where students can explore and make mistakes.
Muller: the curriculum is so dense that there's no time to be creative. We need more time. Summer research is one of these best opportunities to do this.

Questions regarding why the three centers survived.
Uli: the excellence of Cornell is what has helped them survive.
Muller: a lot of the centers have come and gone (they had 10 year terms). Those that have lasted are those that don't have limited funding or limited research. CNF was the first nanofab center in the country. Cornell invests in the center rather than in specific faculty. Our strength was that we were the only university with those facilities. Now other schools are copying us and investing a great deal. They have deep endowments, whereas we have had to look for federal funds which are shrinking.
Lance: it takes a village to make this work and there is human capital to make this work. The right combination of expertise is available here, which is the human side of this. No other school can match our collaborations.

Entrepreneurship at the Graduate Level
Emmanuel Giannelis and Lance Collins

Lance Collins thanked the Ph.D. students for joining the council for the luncheon and for providing their feedback. He pointed out that Cornell Tech gave us the realization of entrepreneurship that we did not have before. The groups that have been the focus up until now have been the undergraduates (the business minor, Kessler Fellows, etc.). There has been some growth in the Masters Program. However, the group that hasn't had as much attention are the PhD students. It's an isolating existence. He asked for the Council's advice on how we can help structure the Ph.D. program. He noted that Eric Young has the expertise to assist us in this endeavor (to help us create a program for Ph.D.'s). Lance recalled his first ECC meeting where he was asked "Why don't we commercialize our technology?" The faculty won't do this, but the students will. It's more likely to happen if a student does this. They're in a strong position to commercialize their research. Lance added, is there are way we can help Ph.D. students join or be a part of entrepreneurship activities? Could they be part of a high-growth company, and if so, what type of training would be needed? He indicated that he would like to create a program where this is possible.

Giannelis noted that they've been discussing Ph.D. entrepreneurship initiatives for some time. This program is designed so that it will not prolong the Ph.D. and it won't take the students out of their career path. This program is not for people who are about to create a start-up. However, it will allow them to be involved in entrepreneurial activities with large corporations and pursue a career in academia.
He added that entrepreneurship is being discussed extensively at Cornell. It fosters commercialization and transitioning of scientific discoveries, as well as stimulates job creation and generates financial returns for universities. He indicated that he attended the 10+ Assoc. Deans Meeting where they discussed the lack of Ph.D. entrepreneurship.

Giannelis explained that the new Ph.D. Engineering Program involves several phases: discovery, feasibility, design and testing, business case, prototype testing, and launch. He contrasted that with the traditional PhD which just involves discovery and sometimes feasibility. He asked the Council, how do we bridge this gap and push it to the launch stage? Giannelis emphasized the importance of experiential learning at the graduate level, such as: the Technology Entrepreneurship Club, eHub and eLab, leadership training, IP workshops, product design, Management Minor, commercialization internships, start-up residencies, LaunchPad associates.

Question: Is this competitive with Cornell Tech?
Lance: This will affect about 10% of our students. Cornell Tech hasn't done well with its Ph.D. program (which is fairly traditional). However, Cornell Tech's Masters' program is very innovative. It's focused on IT Technology and won't affect Cornell in Ithaca.
Comment: A course on innovation would be helpful.
Lance: indicated that there's been a lot of changes in the last few years and we have a stronger sense of who we are today.

The Council expressed support for this entrepreneurship initiative.

<u>Product Design Course for Graduate Entrepreneurs</u>
Mark Hurwitz, Adjunct Professor, Chemical and Biomolecular Engineering gave a presentation on a product design course for graduate entrepreneurs. Hurwitz has an Engineering and Applied Mathematics background with mass transfer and process design experience. He also has over 20 years of R&D management experience including design and implementation of staged and gated processes for new product commercialization.
Hurwitz explained that "Knowledge Workers" are new graduates who are subject matter expert (SME) and who know how to "do things right". He added that industry needs "Knowledge Workers" who know the "right things to do". Knowledge workers have an external focus which: innovates to delight the Customer and works effectively with teams through risk management, continuous improvement and gated design process.

Hurwitz noted that their work is self contained or a gateway to designing for customers, designing for manufacturability, planning and problem solving. He added that some companies have well-managed processes, while others do not. Cornell grads will encounter both! He pointed out that the goal of the course is to upgrade the subject matter expert to being a knowledge worker. This is done through essential tools lectures (5-6 small teams that proposal a product, determine its feasibility and down select through competition and remix teams). This is followed by 2-3 larger design teams that create a paper design, mock-up prototypes, and manufacturing and launch plans. The occasional output is a start-up business proposal ready for initial pilot and prototype.

Hurwitz pointed out that the Essential Tools Lectures cover the following: corporate structure, roles and responsibilities, presentation skills, IP and patent interpretation, gated development, planning and risk management. Lectures during proposal writing include: business strategy examples, start-up vs large cap, consumer vs B2B, requirements (house of 1uality), and return on investment estimation. Lectures during the Feasibility Investigation cover technology availability, project planning, the launch window, risk assessment and mitigation (technical, market, schedule). He added that design lectures include: prototype design, sustainable design, design for manufacturability, user experience testing, planning for manufacturing and launch, and statistics and design of experiments.

Break Out Sessions

During the afternoon, the following questions were addressed:

- Do we have the right approach/topics for the program?
- How is design practiced in your industry?
- In your opinion what are some of the most successful approaches to teaching design and are there technology segments that lead themselves more naturally to teaching design?
- What type of mentoring would be most effective for the fellows?
- Are there any gaps or oversights?

The following was the feedback received from the Council regarding the entrepreneurship program:

- Teams are more successful if they have women on them.
- There's a 60% success of companies where the woman is a co-founder.
- It might be useful to have collaborations between physicians working on a particular problem and engineers.
- Invention vs. innovation. Will only know which it is unless it's a real world problem. Wonders if one could inject this process in an industry environment.
- How do you identify the usefulness of a product? Lance responded: There's the fellowship program so that they can go thru a business planning process to determine if there's a market. It would be a highly guided activity. They would have about 6 months to figure this out. Giannelis added: the minor in management will take care of this. There will be will be more formal education on this.

- Ph.D. student: it would be better to have an internship option that would be more aligned with our future goals.
- We need to bring this design thinking at the beginning of the Ph.D. program so that they're actually understanding the needs. We are still missing an accelerated notion. We need to make bold moves such as an advisors should be considered based on start-up.
- The Stanford biodesign program has worked well. It's more than invention, it's innovation.
- Innovation and creating new products can also take place on something that already exists in the market.
- Getting design into the program earlier is key. Need to provide an environment that de-risks what they do. Fellowships that could combine maybe 2 days a week to support this would be good. Lance responded: as long as we stay within a Ph.D. this might work.
- Is a mentor at MIT, de-risking is important. Students have to go out and raise money for their studies.
- Ph.D. students are subject matter experts. It's very valuable for them to know how their knowledge fits in the world. That course might not fit every one.
- Their company has 230 scientists and 70 Ph.D.'s. Regardless of the discipline, many Ph.D.'s don't' ask the right questions. Very early in the dialogue the student needs to ask the questions, what are we doing now and why. Students need to me mentored on how to have that discussion. This should be added to the curriculum. Scientists need to ask questions at the right time. Lance added: you need to think on your feet. There needs to be a lot of expertise at their disposal.
- Ph.D.'s should be exposed to multi-disciplines so that they're able to do so when they get into industry.
- We need to address both the student and their faculty advisor. What's in it for the faculty advisory so that they will support the student? Lance responded: there's a generational change. New faculty are excited about being involved in more entrepreneurial activities. There's more enthusiasm about entrepreneurship than just a few years ago.
- Student: Took a design course and worked on a virtual business plan. The course needed mentorship (one-on-one) which would have been helpful.
- Try to attract entrepreneurship type Ph.D. students and guide them toward entrepreneurship. Not only harness the resources you have, but also harness new types of students.
- Just the fact that you're infusing entrepreneurial training into the Ph.D. program, you might get another start up or endowment.
- Student: took classes where there are more MBA students and learned more. Having MBA's be part of this program would be helpful. Lance responded: this could be an MBA, since all Ph.D. students must have a minor and this could be one.

- How do we incentivize advisors to have an interest in this? Academia and leadership would be a variable concept. Lance responded: there's a fundamental difference between UG and Ph.D. students. The nature of the Ph.D. student's work and training is that this is deep technology. You're the SME. Mentoring might be the same, however, this would be different because of higher levels of complexities. The SME is the main difference.
- Ownership of the IP is incredibly complex. Potential entanglements are inevitable. There's always some risk. To decrease the risk, the IP needs to be done early in the game to see if this will work. Education about who owns the IP needs to happen. Lance responded: IP depends on who's the student: an UG student owns the IP. However, if it's an employee of Cornell, then Cornell owns the IP.
- There seems to be a segmentation problem. Recommends viewing TED talks, videos online, etc. Provide them with a list of external and internal sources. Create sub-segments. Students could have multiple mentors based on their needs.

After this discussion, Duane Stiller adjourned the ECC. The next Engineering College Council Meeting is scheduled for October 20-21, 2016, in Ithaca, NY.