Columbia Business School
The Deming Center for Quality, Productivity, and Competitiveness

Faculty Study Tour 2016
Pittsburgh, PA

Arconic Technology Group
GE Center for Additive Technology Advancement
Uber Advanced Technologies Center

Participants at GE's Center for Additive Technology Advancement (CATA)

*Photos by Nachum Sicherman

Participants

Columbia Business School faculty from the divisions of Decision, Risk and Operations (DRO), and Finance and Economics were joined by PhD students, associates, Deming Center Advisory Board Members, and guests. Partners from Arconic, General Electric, and Uber also joined many of the presentations.

Nick Arnosti, Assistant Professor, DRO
Vashist Avadhanula, PhD Student, DRO
Omar Besbes, Philip H. Geier Jr. Associate Professor of Business, DRO
Carri Chan, Sidney Taurel Associate Professor of Business, DRO
Fangruo Chen, MUTB Professor of International Business, DRO
John Donaldson, Mario J. Gabelli Professor of Finance, Finance and Economics
Nelson Fraiman, Professor and Director, The Deming Center, DRO
Wenqi Hu, PhD Student, DRO
Yashodhan Kanoria, Assistant Professor, DRO
Zhe Liu, PhD Student, DRO
Costis Maglaras, David and Lyn Silfen Professor of Business, DRO Chair
David Niles, Deming Center Advisory Board, President G100 Companies
Paul O'Neill, Deming Center Advisory Board, 72^{nd} Secretary of the U.S. Treasury
James Peterson, Deming Center Advisory Board, Director Corporate Initiatives GE
Nachum Sicherman, Carson Family Professor of Business, Finance and Economics
Bob Silvers, Deming Center Affiliated Member, Managing Director SSA
Burt Steinberg, Deming Center Advisory Board
Abigail Talcott-Schlaifer, Associate Director, The Deming Center
Gowtham Tangirala, PhD Student, DRO
Kai Yuan, PhD Student, DRO
Fanyin Zheng, Assistant Professor, DRO

Pittsburgh Faculty Study Tour

In December 2016, the Deming Center at Columbia Business School hosted a study tour to Pittsburgh, Pennsylvania. Faculty, doctoral students, associates, Board Members, and friends of the Center attended several presentations, each of which focused on the role and use of disruptive technology in industry.

The group attended presentations with Arconic's Technology Group, GE's Center for Additive Technology Advancement, and Uber's Advanced Technologies Center.

The objective of the trip was to broaden faculty and student's exposure to industry and build bridges between theory and practice, thereby enriching the curriculum at the Business School.

Uber Advanced Technologies Center Presentation by Dr. Jeff Schneider

Columbia Business School faculty, PhD students, and associates were joined by partners from GE and Arconic for a presentation on driverless car technology.

The first presentation upon arriving was with Dr. Jeff Schneider, Engineering Lead for Machine Learning at Uber Advanced Technologies Center (ATC). Dr. Schneider is a research professor in the Robotics Institute at Carnegie Mellon University, currently on leave at Uber where he is working on the intelligent algorithms that ensure the smooth deployment of self-driving cars.

Uber ATC was established in January 2015 as the R&D hub for Uber's engineering team dedicated to developing autonomous cars, mapping, and vehicle safety. By September 2016, they had a small fleet of self-driving cars on the streets of Pittsburgh with plans for 100 by year's end. During this testing period, a human engineer sits behind the wheel, ready to take over should the need arise. The wheel senses any torque and then exits autonomy mode to return control to the driver.

Each car is equipped with GPS, cameras, and LiDAR, a laser range finder that senses objects to make high-resolution three-dimensional maps. As each autonomous vehicle drives around town, the scanners are sending back data in real time that is used to build intricate and complex 3D maps of the dense, urban setting.

Uber has several competitors in this emergent technology, most notably Google and Tesla. While Google has been experimenting with self-driving cars for a decade and has access to superior technology, Uber's advantage is that they are already predominantly a transportation company. This enables them to experiment and understand nuances in real time and not in controlled experiments. They have a constant stream of data being sent back 24 hours a day. Tesla is pursuing a somewhat different model and hypothesis. Their goal is to augment the driver's experience through enhanced features, mostly on the highway. Uber's model is to be in dense, urban settings and completely remove the driver from the equation.

At Uber, self-driving cars is not merely a futuristic pursuit, but an essential strategy of their business model that would cut costs and grow their market share. Vehicles with self-driving capabilities will also help Uber integrate its other businesses including UberEats and Otto, a self-driving trucking company they recently acquired. Rather than managing three different business units, everything falls within the same framework where a vehicle with self-driving capability either transports a passenger, food, or materials.

Dr. Schneider also discussed many of the potential ramifications of the driverless car revolution on the future. One of the things Uber is betting on is being able to bring the cost of a ride down so significantly that the cost of using the ride hailing service will eventually be cheaper than buying and maintaining a car. The technology will disrupt many industries including city's public transportation networks, automotive insurance, and car manufacturing. Another implication is the infrastructure that is currently dedicated to parking would be dramatically decreased, opening up great amounts of space in urban areas. Autonomous cars have the potential to significantly reduce traffic as well as deaths caused by car accidents.

Professor Fraiman with one of Uber's autonomous cars on the streets of Pittsburgh

Dr. Jeff Schneider of Uber ATC

GE Center for Additive Technology Advancement
Presentation by Jennifer Cipolla

GE's Center for Additive Technology Advancement sits a few short minutes from Pittsburgh International Airport and just 40 minutes from downtown. Opening in April 2016, CATA is GE's hub for innovation in additive manufacturing design and application. "CATA is on the forefront of implementing industrial applications of additive manufacturing for the benefit of all GE businesses," says Jennifer Cipolla, who runs the facility. CATA's role is to experiment, train and develop the technology so that it can be turned over to each of GE's eight businesses and put into immediate production. With 50 employees and 35+ machines, there are currently 250 projects flowing through CATA.

Additive technology is already revolutionizing manufacturing and the future is poised to be completely upended by this emergent technology. Already, GE is using 3D printed fuel nozzles in their jet engines. This small but critical component used to be comprised of 20 parts, all outsourced, that needed to still be welded together. With additive, the nozzle is now printed as a single piece, the wait time has been reduced by 20%, the fuel economy has been reduced, and the performance is better. GE's factory in Auburn, Alabama is now printing 35,000 fuel nozzles on 50 machines running 24 hours a day, 7 days a week, 365 days a year.

Additive technology, in contrast to traditional subtractive manufacturing, enables users to construct parts from the ground up. CATA's direct metal laser melting machines use powdered metal and build layer by layer, each one the thickness of less than a strand of human hair. Building up this way ensures that hardly any materials are wasted and enables one to make complex parts and geometric shapes that would be impossible using subtractive methods.

There are limitations to the technology. As Jenny pointed out, the processes are so new and there is no established protocol or manual on additive manufacturing. In fact, no one in the world is an expert in additive design as of yet. The goal at CATA is to keep pushing the technology, adapting to new and emergent developments while trying to figure out how to get the structural properties that were achieved through traditional forging and heating. Even with the increased efficiency with materials and printing, post-production remains a challenge. For the fuel nozzles, about 20% of the investment is in printing, with the remaining 80% in post-production processes.

To continue advancing additive, GE is in the process of acquiring Arcam, a major manufacturer of additive manufacturing machines as well as a producer of advanced metal powders. This solves one issue which is that capacity is an issue for outsourcing production. There are not, as of now, many third parties who have the ability to meet demand of a large production run. This vertical acquisition symbolizes GE's ambition to be the front runner of innovation in this area, pushing the boundaries and driving the industrialization of additive manufacturing.

Participants before Jennifer Cipolla's presentation at CATA.

Below, PhD student Wenqi Hu introduces herself and her research to Paul H. O'Neill, 72nd Secretary of the U.S. Treasury and Deming Center Advisory Board Member.

Chandeliers in the lobby at CATA. There are five pieces made up of 160 polycarbonate parts that were printed on their machines. 5,000 LEDs light up the globes, each with their own IP address. Normally, the parts would have taken a year of total print time but CATA was able to do it in just 2 ½ months running 12 of their machines 24 hours a day.

GE Healthcare
Presentation by Jimmie Beacham

At GE Healthcare, they are always asking two questions: How do we modernize healthcare and how do we open up the design space to do so? Additive is a big part of the answer to both questions. They view healthcare as a technology business with a diversity of high tech products including imaging, pharma, monitoring, contrast, life support, molecular, surgery, information and so on. Manufacturing such high tech products is not just an assembly business, but requires over 200 manufacturing technologies.

Additive manufacturing for GEHC fits into the whole product life cycle, from rapid prototyping to tooling, and from part manufacturing to point of use to reduce inventory. Additive manufacturing has a broad spectrum of applications including plastic and metal components, microelectronics, life sciences and biomedical, and ceramics. It is thrilling to imagine the possibility of making living cells or even print organs in the future. The major challenges GEHC envisions pertain to the available material types which will rely on the development of material science, new supply chain, IP controls when outsourcing is involved, and high engineering standards.

One important application in the health care sector is Direct Write printing, a 3D electronics printing technology. It prints in sizes from 0.01 to 1 mm with 5 axis capability and can print on a wide range of materials and even 3D surfaces. The scalability to meet high volume production requirements and the capability of low temperature processing (70-150˚ Celsius) are attractive. As a result, there is a wide variety of applications for Direct Write: antenna printing, shielding, conductive adhesives, embedded sensors, and rapid prototyping.

In terms of the supply chain, 3D additive printing helps GE Healthcare in balancing their bargaining power in price negotiations with suppliers and retaining more flexibility in printing in-house instead of requiring expedited supply and shipping. They are currently spending more than $700 million a year in logistics, expediting various parts via 3rd party carriers. The focus of GE Healthcare has changed over the last 10 years to not only advance technology but to improve work flow and additive manufacturing will play an even more pivotal role in the future.

Arconic Technology Group Presentation by Dr. Ray Kilmer

Arconic is a global metals manufacturer specializing in aerospace and automobile manufacturing, working primarily with ceramics and metals such as aluminum, titanium, nickel and their alloys. With over 42,000 employees and $12.5 bn in revenues, Arconic has a globally expansive footprint in 156 locations across 25 countries. Arconic split from Alcoa in October 2016, primarily as a reaction to Berkshire Hathaway's acquisition of PCC, their prime competitor in aerospace manufacturing but also as a means to streamline operations, with Alcoa remaining responsible for standard commodity type products and Arconic focusing on customized technologies and the associated R&D.

The Arconic Technology Center (ATC) is located outside Pittsburgh and houses roughly 450 technologists. In contrast to GE's CATA facility that serves as a go-between R & D and production, the ATC serves as an integrated facility that offers both these services under one roof. Indeed, ATC houses a $60 mn production scale metal powder facility that directly serves as an input to their 3D printing additive technology. At ATC, they produce everything from the pop top on soda cans to aluminum spark plugs to casting and manufacturing jet engine turbine blades. Arconic is the market leader in aerospace manufacturing. They produce 90% of the components found on a jet engine, from the tiny rings and fasteners that minimize the pressure differential and protect the airplane by channeling lightning, to the turbine blades that serve as the main propellants for the aircraft. In fact, every A380 aircraft contains almost a million Arconic fasteners.

Ray Kilmer, Chief Technology Officer (CTO), has been tasked with making operations more efficient by consolidating and streamlining the research departments that had been acquired over time and coming up with a common unified framework to make the department more intimately connected with the greater business strategy. Under this framework, subject experts in R&D stay in constant touch with the business and marketing units to ensure that projects reach their full potential in a timely and feasible manner.

Stage A – Idea Generation and Concept Definition
Stage B – Concept Development and Design
Stage C – Test Lab Scale Demonstration
Stage D – Demo & Pilot: Pre-Production Plant Scale
Stage E – Full Scale Production & Roll-out

Projects are terminated at whichever point they are deemed unviable. This framework helps in developing a timeline for monitoring progress and controlling investment by framing specific requirements at every stage of development. For every 100 projects undertaken, roughly 40 projects go successfully through all the five stages. Each project, once proved to be viable in the middle stages, is directly linked to the business strategy that expands upon how to capture business ideas, estimate plans, and ultimately implement and realize impact. The time range for technology development/implementation ranges from 12-18 months for smaller projects to 3-5 years for more ambitious projects. For example, Arconic developed a next generation wheel for trucks that reduced their weight by 5 pounds by using a newly designed alloy with an innovative design. This entailed revamping and devising new manufacturing processes. The project took 18 months from conception to rollout. Along the way, the lessons learned from the project made existing processes more efficient and thereby saved more money than what was required for the initial project. Thus, the project ended up funding itself.

Additionally, the CTO has a discretionary fund to invest and allocate to riskier projects that promise bigger reward. There is also a Growth & Innovation group which looks for grand challenges to solve longstanding, consequential issues that plague the industry. This group talks to business units and customers to identify high-risk, high-reward challenges. One example of such a project had to do with designing ceramic shells that jet engine turbine blades are ultimately cast into. The usual manufacturing of these blades is very complex and difficult, not to mention expensive. Consequently, the industry is usually very reticent to change the design and formula of the process. The Growth & Innovation group managed to increase the overall capacity two-fold with existing capital by investing in robotics and different ceramic dipping approaches that require fewer dips of molds into slurries. They ultimately reduced the number of dips from roughly 13 to four with improved control on metal cooling rates.

The biggest challenge Arconic faces is to constantly innovate their processes to stay one step ahead of their competition. Another priority is scheduling and timing project development so as to not cannibalize the revenue generated by their own competing innovations. However, thanks to the data available for collection and increased computational ability, Arconic is no longer limited by these technical shortcomings. Increasingly, they are heavily investing in using this data and employing complex computational models and tools such as stochastic modeling and optimization techniques to better make their process and business decisions and to function more efficiently and profitably.

Arconic Technology Group
Presentation by Sergio Butkewitsch Choze

The CBS cohort meets with Rod Heiple, Sergio Butkewitsch Choze, Ray Kilmer and John Siemon at Arconic Corporate Center.

At Arconic, Dr. Sergio Butkewitsch Choze heads the *Advanced Analytics and Optimization, Manufacturing Intelligence and Automation Technologies* division where he leads of team of statisticians and engineers dedicated to developing solutions to productivity and efficiency in manufacturing and automation based on complex data analytics and optimization techniques.

Arconic relies on a three-step process to make data-driven decisions:

1) Data Generation and Collection

Manufacturing processes are optimized and designed in such a way to make it is easy to collect data. For example, in automation processes involving robots, optimization techniques are used to satisfy cost requirements and some pre-specified technical requirements of the system.

2) Data Visualization

The data visualization team contextualizes the range, scale, and variety of data available in a lucid and intuitive manner. This aids in correctly formulating questions and provides means of seeking the correct answer, thereby serving as the starting point of data analysis.

3) Modeling and Simulation

Once the data is visualized, the number crunching begins. Physicists and engineers develop computational models that solve a set of representative equations to predict the behavior of complex systems. For example, in a structural engineering team, a problem would be to design an airplane wing such that it can withstand twice the highest possible operational load, to guarantee survival even under extreme conditions. Subsequently, computer models are developed that simulate these stress tests. Putting the two together, the engineers arrive at the optimal wing design that is guaranteed to pass the test.

One example of how data analysis improves process efficiency is in melting technology. In melting processes, a charge load is placed inside a cast and the burner is turned high. If the burner is set arbitrarily high, it not only melts the charge but overshoots the temperature which results in unnecessary fuel consumption and also takes longer time. Using physics-based models, technicians can now predict exactly how much energy would be necessary to maintain the temperature in the desired window without overshooting, simultaneously decreasing the energy used and increasing productivity. Add to that the fact that such applied knowledge is transferable across different production processes and this makes the efficiency even higher.

One of the challenges in the world of data analytics is arriving at a vision to identify areas where knowledge of data is either required or desired. Once the data source is identified, it also has to be properly integrated with all the other different sources of data. After all, data-driven decisions are possible only if the right people have the right data at the right time in the right form.

Professors Zheng, Chan and Fraiman get an Uber ride in a red pickup truck.

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