Shale Gas Optimization

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Message from PITA Co-Directors

For the past 20 years, the mission of the Pennsylvania Infrastructure Technology Alliance (PITA) – funded by the Commonwealth of Pennsylvania’s Department of Community and Economic Development – has been to connect Pennsylvania’s companies with the Commonwealth’s world-class university researchers and their students to promote economic development in Pennsylvania. With help from PITA, Pennsylvania is increasing its market competitiveness through the development of new technologies and process improvements.

The PITA program is working and continues to exceed expectations. Accomplishments now include funding over 1,120 technology and process improvement projects in partnership with more than 440 Pennsylvania companies, and obtaining more than $2 of leveraged funding from industry and federal resources for every $1 of state funding. PITA has also mobilized more than 430 faculty members and 1,850 students to work on Pennsylvania-specific technology, process improvement, and educational outreach projects, and enabled 12 start-up companies created from PITA-sponsored technologies.

As always, we welcome partnerships with new companies.

PA companies that are interested in working with faculty/graduate students on short-term technology development/process improvement projects should contact the PITA Associate Directors Chad Kusko, Lehigh University, chk205@lehigh.edu, or Colleen Mantini, Carnegie Mellon University, cmantini@cmu.edu.

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Shale Gas Optimization

To some, “optimization” may simply be a word to use when “better” won’t do. But to Ignacio Grossmann, professor of chemical engineering, optimization is the key to unlocking huge cost savings for shale gas companies, who often weather price volatility when a drop in crude oil market prices takes a toll on oil and gas production and distribution. While not without historic precedent, these ups and downs pose economic challenges.

Grossmann’s process engineering strategy, for which PITA provided seed funding, uses novel mathematical programming models to save companies money, time, and resources. Grossmann, along with his previous Ph.D. students Markus Drouven and Linlin Yang, and Universidad Nacional del Litoral Associate Professor Diego Cafaro, pioneered research in this area. They spent four years focused on the strategic planning, design, and development of the shale gas supply chain network, including water management in shale gas operations.

When world crude oil and domestic natural gas prices declined dramatically in 2015, threatening the profitability of many operators, it resulted in more than 65,000 layoffs throughout the industry, according to Forbes Energy. Grossmann and his team used their optimization techniques to try to reverse this trend by helping companies make better investment decisions that relate to the planning of drilling shale gas wells. As part of this research, the group determined the most cost-effective drilling and completions schedule for a shale gas development area in Southwestern Pennsylvania that contained over 18 well sites and 40 prospective wells. This research was published in the AIChE Journal in 2016.

“In this project, we used novel mathematical models [known as mixed-integer programs] and related optimization software to rigorously evaluate millions of possible development strategies and then provide clear recommendations for action,” explains Grossmann. “It is very exciting for us and our industry collaborators because there is currently no similar computational strategy for planning in the shale gas industry.”

Currently, spreadsheets are used to plan out decisions, such as when and where wells should be drilled. Companies do not have the capabilities to use strategic computer tools like the ones that Grossmann’s group uses to make long-term development and planning decisions.

“We hope that the research we are doing will help grow businesses and promote growth in regions that rely on shale gas production as an important economic driver.”

— Ignacio Grossmann, professor of chemical engineering, Carnegie Mellon University

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Partnering with Industry and Keeping Talent in PA

Most researchers working towards their Ph.D. in chemical engineering know one thing: if they want to go into industry, they will have to leave behind the project that inspired their passion during their academic career.

Markus Drouven, however, thanks in part to PITA seed funding, had the unique opportunity to continue his academic pursuits in industry after graduation.

Drouven, who worked during his Ph.D. on the optimization for shale gas project with Carnegie Mellon University’s Chemical Engineering Professor Ignacio Grossmann, was eager to see if their theories would hold up in real-world situations. Grossmann had a contact at Pittsburgh-based EQT Corporation, the largest natural gas producer in the country, and reached out about a collaborative effort to put their optimization techniques to the test.

“Our project was focused on building mathematical optimization models to support shale gas development at a very high level,” says Drouven. “However, by partnering with EQT, we were able to look at the practical problems that businesses face. EQT was very excited as well to give our model a shot—they have a strong culture of innovation, and were curious to see what kinds of solutions and schedules our model would propose in comparison with how they had done things historically.”

Drouven met with EQT twice a month throughout the project, and had access to the company’s data, as well as its experience.

“EQT would keep us on track because they knew the industry,” says Drouven. “They would say, ‘I see you considered the technical constraints, but what about seasonal constraints?’ They made sure we stayed on the ground and we didn’t do work from an ivory tower.”

One of the many problems Drouven addressed that was of concern to the industry was how to reduce the number of water hauling trucks on the road. Large trucks are required to deliver water for shale gas development, but reducing truck traffic on the roads is better for everyone—it helps to reduce accidents, decrease road wear and tear, and saves the shale gas company money. Drouven and the CMU team, which included Grossmann as well as ChemE Ph.D. student Linlin Yang and Universidad Nacional del Litoral Associate Professor Diego Cafaro, proposed strategies for delivering water through pipelines instead of via trucks.

“We were able to help practitioners in this industry make better, faster, and safer decisions,” says Drouven.

Upon graduation, Drouven also benefited from the collaboration: EQT offered him a position in the company. Now, Drouven is the Optimization Engineering Team Lead for EQT, where he continues the work he began in academia and makes an impact in his community, because of the collaboration between PITA, EQT, and CMU.

“I decided to go to CMU because I knew the work I would do would have exposure to people from industry, and the work we were doing made a difference,” says Drouven. “At the end of the day, our research mattered in the area where we live and work.”

Using these optimization techniques, Grossmann and his group were able to increase the overall gas production and profit while decreasing the number of wells needed. Their recommendations also improve equipment utilization for pipelines and compressors.

“There is a lot of pressure on upstream companies [focused on production and exploration] to remain profitable when the price of gas decreases. This means that the role of optimization becomes even more important to help make better economic decisions for these companies and our communities at-large,” says Grossmann. “We hope that the research we are doing will help grow businesses and promote growth in regions that rely on shale gas production as an important economic driver.”

For this project, Grossmann and his team had the unique experience of being able to work with Pittsburgh-based EQT Corporation, an industry collaborator and largest producer of natural gas in the county.

Grossmann emphasizes that this work could not have been achieved without PITA, as PITA provided the seed funding, which in turn helped him to apply for a grant from the National Science Foundation. The funding from both sources supported Drouven for his Ph.D. degree over a four-year period. Drouven was later hired by EQT to begin the project.

“PITA funding has been a mechanism for seed funding to explore projects, which in the case of shale gas later led to major funding. It gives us the freedom to explore,” explains Grossmann. “This project with PITA was also very nice because it led to EQT hiring my student, and he has been charged to put together a new group for optimization.”

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Since its founding, PITA has fostered interest in science and technology among youths in Pennsylvania. The alliance stands at the forefront of education and research, and develops programs that introduce engineering to youths of varying ages. The goal is to encourage interest in STEM throughout the community.

One program that PITA has supported is Moving 4th Into Engineering. Approximately 35 fourth-graders from across Pittsburgh come to Carnegie Mellon University’s campus each Spring to participate in activities that introduce them to the world of engineering. Students collaborate with CMU faculty in a variety of activities, including crafting with polymers, building and launching rockets, and designing their own solutions in response to real-life problems. Through interactive experiences and with the help of the staff, students learn how engineering shapes many of the things they experience every day. This early exposure to engineering aims to excite young students about science and math and encourage them to pursue technical courses throughout their education. This program introduces fundamental concepts to youths and fosters interests in such educational opportunities.

Another PITA-funded outreach program is the Summer Engineering Experience for Girls (SEE), a two-week program that began in 2007 for middle school girls. SEE aims to develop the girls’ problem-solving skills, encourage teamwork, and allow the girls to apply their thinking to real-world problems. Participants form groups and explore a topic of their own interest, such as using biomass to power devices and zero-energy homes. The students then gather research via hands-on activities before presenting their findings. They work alongside peers with guidance from multidisciplinary female scientists. SEE also connects the girls with engineering faculty and industrial engineers.

“The overarching goal of this program is to help young girls realize their interest in science and technology,” says India Price, a CMU mechanical and biomedical engineering major and previous SEE mentor. “A lot of the girls really like math or physics or chemistry, but they don’t really know what opportunities are out there. This program is designed to expose them to all kinds of engineering and help them start thinking about the possible careers they might want to pursue.”
Lehigh University’s Advanced Technology for Large Structural Systems (ATLSS) Engineering Research Center supported undergraduate engineering students through a PITA award for its Research Experience for Undergraduates (REU) program in Summer of 2017. The program provided students with the opportunity to conduct engineering research on active projects in the ATLSS Engineering Research Center.

Some research focus areas in the REU program included: modeling power distribution structures in the Lehigh Valley; investigating the manufacturability of orthotropic steel bridges; developing a mobile sensing system for bridge monitoring; and studying the long-term behavior of geothermal deep foundation systems.

“PITA provided me with exposure to the world of research through my participation in the ATLSS REU program, including the opportunity to conduct research on the performance of geothermal deep foundation systems to which I would not have otherwise had the opportunity to learn about,” says Ryan Bonshak, a mechanical engineering major at Lehigh University. “This research provided me with first-hand experience as to how to approach a research problem and methodically work through the problem to discover behaviors and characteristics that previously were not known.”

Each REU student conducted research under the guidance of a faculty mentor and a graduate student mentor.

The REU program also included several professional development seminars provided by Lehigh University’s Career and Professional Development Department. These seminars included topics on resume development, searching effectively for a job or internship, and interviewing tips for future job searches.

The program toured various Pennsylvania companies, such as High Steel Structures, Lehigh Heavy Forge, and Intertek. These tours connected the students with companies and highlighted operations associated with the students’ areas of interest.

“The ATLSS REU program, through this research, its professional development workshops, and through industry tours, provided a unique complement to my academic studies and equipped me with a professional skillset to prepare me for my future professional endeavors,” says Bonshak.

Funding for the research was provided through agencies such as the National Science Foundation and the United States Department of Transportation.
Snake-like Robot To Revolutionize the Electrical Industry

Matt Bilsky, founder of Impossible Incorporated LLC and post-doctoral student and adjunct faculty member at Lehigh University, has invented a patent-pending, snake-like robot that will revolutionize the electrical industry.

Running wires through walls is currently a messy and expensive task. To run wires across a room, electricians must break into the wall at each stud and joist, and then drill a hole in the wall through which they can pull wires. After wiring, electricians must patch and paint the holes they drilled, which increases their task’s cost. The potentially hazardous opening of the wall results in large messes and damage that cannot be perfectly patched.

Bilsky’s one-inch diameter robot can be inserted through an outlet-sized hole and teleoperated.

Impossible Incorporated LLC has partnered with Lehigh University through two PITA grants to support the development of the robot. The first grant develops the sub-systems of the robot, and the second focuses on the higher-level systems enabling its function.

The first PITA grant allows collaboration with Professor Brandon Krick, who runs the Lehigh Tribology Laboratory. Krick’s group has expertise in studying the wear on mechanical systems. This knowledge has furthered the development of the mechanical gear boxes that power the system. Additionally, study of the behavior of the flexible drive shafts helps to identify a viable casing solution to protect the shaft within the robot.

The recently-awarded second PITA grant will enable collaboration with Lehigh Professor Subhrajit Bhattacharya, an expert in robotic path-planning and simulation. This PITA grant will support Impossible Incorporated LLC’s development of a wall-mapping system that can scan and map existing obstacles within a wall. This system will use algorithms to autonomously guide the robot. The results of this collaboration will enable electricians to identify where on a mapped wall they wish to drill.

“Through the PITA program, I am practicing what I teach by serving as the industry partner for the project and enabling graduate students to work on real-world projects that illustrate the power of technology transfer and industry-academia partnerships,” says Bilsky, who also teaches the Technical Entrepreneurship Capstone course at Lehigh University. “The PITA program has afforded me the opportunity to have world-class researchers advance the project, and is allowing me to take my pre-revenue startup to the next level by pursuing federal grants and commercialization opportunities.”

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When inside a wall or ceiling, the robot drills all necessary holes in studs and joists along the way to its destination. The robot reaches its destination, attaches the wires, and returns through the wall, pulling the wires behind. Markets and applications for the robot and its technologies include: home inspection, aerospace, disaster recovery, and assistive technologies/prosthetics.

The robot’s movements mimic a regular drilling strategy: setup, drill, move, repeat. A system of rigid, snake-like, repositionable links makes this happen. A large, powerful motor is placed outside the wall. Rotational energy transfers from the motor through the robot to a gear box proximal to the drill bit in the wall using a high-speed flexible drive shaft. Once the robot maneuvers to the drilling location, it braces itself within the cavity, then locks rigidly to withstand the drilling forces. The robot is essentially a traditional power drill split in half.

To make the robot strong yet agile, researchers have invented a novel motion method that allows the robot to move within a plane, such as a wall or ceiling, while also being able to move out of the plane. The robot can also advance through drilled holes.

For more information, contact Matt Bilsky: matt@mattcomp.com, Brandon Krick: bakrick@lehigh.edu, Subhrajit Bhattacharya: sub216@lehigh.edu
PITA is an **industry-led program** that enables companies to identify opportunities for the University, through its faculty and students, to provide expertise and capabilities that they may not otherwise be able to access.

PA companies gain access to **faculty expertise, university equipment and students.** University faculty and students are afforded the opportunity to work on **real-world, market-driven challenges** confronting PA companies.

Faculty and students assist companies in creating technology of the future and enhancing the competitiveness of PA companies with the goal of the creation of jobs in Pennsylvania and the retention of highly trained/educated students in Pennsylvania.

PITA Technology Focus Areas include:

- Transportation
- Telecommunications and Information Technology
- Facilities
- Water Systems
- Energy & Environment
- Public Health & Medicine
- Hazard Mitigation & Disaster Recovery

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