## Education

This fall semester 2018 Dr. Petr was asked to again teach the class MNGN 333, which is part of the explosive’s minor degree program at the Colorado School of Mines. The class is full and includes three international students. This course gives CSM students and unique opportunity to learn hands-on about explosive safety, products, properties, applications, and use. This class also visited Orica USA in Watkins where the students toured the facility, learned from industry expert Julie Bingley, and gained an overview of different products and applications such as mining and surface blasting. The class will also have three laboratory sections at the research laboratory in Idaho Springs where the students will study practical explosive safety, explosive products, and explosive properties such as ground vibration, velocity of detonation (VOD), detonation pressure, and sympathetic detonation.

AXPRO was proud to celebrate Dr. Vilem Petr and Scott Narreau’s 10-year anniversary in 2018 for teaching CDOT students about avalanche mitigation methods and the established avalanche management program. Every year, the AXPRO team educates hundreds of CDOT employees, both new and veterans, on various avalanche control methods and procedures. A general 2-day course is offered in both Durango, Poncha Springs, Colorado and Loveland Ski Area, while the more practical courses in hand-charges, case-charges, rock fragmentation, and unexploded ordnance are taught at the ERL in Idaho Springs, Colorado.

### Dr. Petr and Scott Narreau’s 10-year celebration.

In addition to providing the state-certified explosives training program, for the past ten years we have been proved about 150 courses for the Practical Explosives Training School (PETS) for industry workers, professionals, and explosive handlers who are looking to obtain or renew their explosives permit. AXPRO is beginning two new explosives training programs with Freeport-McMoRan’s Henderson Mine and the National Forest Service. Employees at the Henderson Mine will receive training in explosives-handling as
new underground miners and National Forest Service employees will be taught about the various explosive applications for park service methods. For more information on these programs please visit our website: www.axpro.mines.edu-PETStraining. AXPRO will also be providing PETS training for the Division of Occupational Safety and Health of the Washington Department of Labor and Industries.

The AXPRO team have been offering two annual courses on experimental techniques in explosives engineering every spring and summer: High-Speed Research and Experimentation (HIS) and Flash X-Ray and Ultra-High-Speed Imaging Methods for Research and Experimentation (XUHIS).

The four-day XUHIS course is a four-day course was taught in March, during Mines’ Spring Break. This course was developed and supported by a short course from Specialized Imaging Inc., a world leader in ultra-high-speed framing digital imaging, and instructors Mr. Frank Kosel, Mr. Chris Tenney, and Mr, Peter Laurence where students worked one-on-one with instructors on specific technical problems of high-speed imagery and camera setups to teach twenty-four students from the Missouri University of Science and Technology (MS&T) the principles of flash x-ray systems, ultra-high velocity impact, experimental techniques for capturing detonations, ballistic and impact theory, metallurgical observation and energy partitioning, engineering considerations in hyper-velocity, and how to effectively implement flash x-rays.


AXPRO and Dr. Petr offered a long-distance class for students from MS&T take the Special Use of Explosives course in Summer 2018. In this course, students were taught about the applications of explosives towards various industries, including the areas of rock fragmentation, well perforation, avalanche control, explosive welding and engraving, and military and defense. This is the fourth year that Mines has maintained a collaboration with MS&T, and AXPRO is once again very excited to be offering an explosives engineering course to MS&T students in 2019. A new course is being developed for numerical modeling of explosive applications and will be offered in the summer of 2019.
This September, Dr. Vilem Petr and Mr. Frank Mazella, Learning Products Manager at Ametek Vision Research, taught the HIS course, which is supported by Ametek Vision Research, a world leader in the manufacture of high-speed digital cameras. Sixteen students signed up for and took this course, including the employees of National Laboratories, as well as two Colorado School of Mines graduate students. This course teaches both inexperienced and experienced students high-speed imaging framing, lighting and lens selection, triggering methods, and analysis strategies. Students are educated in establishing best practices for civilian and military applications. They are offered the opportunity to conduct practical field exercises, and to participate in a professional network of explosives engineering and high-speed imaging experts.

In Spring 2018, Dr. Petr was invited to begin a partnership with the University of Denver (DU) Daniel Felix Richie School of Engineering and Computer Science to teach twenty-four graduate and undergraduate students an Introduction to Explosives Engineering course. This was a successful course,
and students were able to visit the Explosives Research Lab in Idaho Springs, Colorado to receive some hands-on experience. Dr. Petr enjoyed teaching this course and hopes that DU and CSM/AXPRO can continue to collaborate on future courses on explosive engineering.

The AXPRO team is excited to share the progress of the new graduate program in Materials Science, the Materials Science Graduate Program with an emphasis in Energetic Materials (Explosives). This special emphasis in Energetic Materials (Explosives) is now offered to students pursuing Ph.D. and M.S. degrees in Materials Science. Professional students are currently being recruited from U.S. National Laboratories, government agencies, and private-sector companies. Graduate students are closely mentored by subject-matter experts and industry professionals and will be allowed the unique opportunity to investigate material and material properties under dynamic loading, energetic materials undergoing detonation, high-fidelity technology, post-detonation phenomena, and material behavior under large-rate deformation and strain. Please click this link if you are interested in finding out more.

**AXPRO Giving**

The AXPRO team is pleased to be continuing its new industry and government partnership program, AXPRO's Annual Constituent Collaboration Engineering Student Success (ACCESS) program.

**AXPRO-ACCESS** is designed to improve relationships between industry and the Advanced Explosives Processing Research Group (AXPRO). AXPRO leverages existing explosives engineering synergy across campus to meet the needs of industry via mutually beneficial partnership programs involving access to faculty, students, and state of the art research facilities.

The **AXPRO-ACCESS** program is the conduit for academia and industry to exchange ideas and establish longstanding partnerships. The new Energetic (Explosives) Engineering program will provide the next generation of explosives engineers for industry and government agencies. It is essential that AXPRO faculty and staff are exposed to current industry projects to ensure that they incorporate current industry problems in our Explosives Engineering curriculum. Industry support and engagement with AXPRO-ACCESS is critical in maintaining and growing the pipeline of high-quality explosives engineers for industry as well.

Please visit our website to learn more about AXPRO-ACCESS: [AXPRO-ACCESS](#)

**Visits and Collaborations**

AXPRO is pleased to be continuing its long-term partnership with Special Aerospace Services (SAS). SAS is a female owned corporation headquartered in Boulder, Colorado with field support offices in various U.S. locations. Special Aerospace Services is a tactical engineering and advanced manufacturing firm with more than a decade of experience providing cutting-edge solutions to aerospace, aviation, defense and energy organizations worldwide. Cameron Brown, a student in the Materials Science with emphasis in Energetic Materials graduate program, is an engineer at SAS, and is currently working with AXPRO to conduct his thesis research in the additive manufacturing of energetic materials.

Several researchers from Los Alamos National Laboratory (LANL), Travis Peery, Jonathan Mace, Tariq Aslam, and Terry Salyer, visited the Colorado School of Mines and gave lectures to the Explosives Engineering course and the research team on detonation physics. AXPRO is continuing to work with LANL, and Eduardo Lozano, a doctoral candidate and AXPRO team member will be working with LANL on numerical modeling and instrumentation this next semester.
Cameron Brown working on additive manufacturing research at the Colorado School of Mines.

Further, Dr. Eric (Buck) Bukovsky, a research scientist at Lawrence Livermore National Laboratory (LLNL) and Mines alumni, gave a lecture on explosive application use at LLNL.

This summer, AXPRO hosted a Girl Scouts troop from the City of Golden at the Explosives Research Laboratory and Edgar Mine in Idaho Springs, Colorado. The troop spent the summer day watching several explosive demonstrations, enjoyed a BBQ lunch afterwards, and then took a tour to the Edgar Mine. The AXPRO team very much enjoyed the opportunity to teach the girls about explosives engineering and promoting future careers in this very unique discipline. AXPRO will be providing opportunities to collaborate again.

Visual Researched sponsored The SloMo Guys to visit AXPRO to record multiple explosive events using the latest Vision Research High Speed Cameras (Phantom v2640 and v2512). In the video, a variety of explosive equipment were used such as shock tube, detonating cord, shaped charges, etc. The AXPRO team prepared all the explosive charges and provided the test facilities. The video currently has more than 2.5 million views and can be found in the following link: https://youtu.be/dHfQYGGUS4U Disclaimer: Contents of the video not associated with AXPRO or the Colorado School of Mines explosive program.

Research

Pressure Wave Characterization for Industry Cleaning

AXPRO has been conducting research with the Electrical Power Research Institute (EPRI) to characterize the detonation and shockwave physics associated with the propagation of an explosive gas mixture, “Bang&Clean®” technology (by General Electrics for the USA), which is currently used for slag removal in boilers at power plants. The bag(s) is filled with an explosive gas mixture and ignited. The resulting shock
wave(s) and boiler tube vibrations remove the slag that is deposited on their surface. This research, which endeavors to provide guidance to the electrical power industry on tube failure risk and safety distances required for pressure-wave cleaning operations through experimental measurements, analytical and theoretical calculations, and metallographic analysis. The blast parameters of the pressure wave process were experimentally measured and analyzed at the Explosives Research Laboratory using piezoelectric sensors and high-speed imaging cameras VEO 710s. Almost 50 experimental tests were performed and analyzed to better understand safety distances for different types of blasts. In addition, several tests were performed using dynamite and detonating cord to provide validation between solid explosives and gas explosives.

*Experimental setup and testing of “Bang&Clean®” technology at ERL.*

**Evaluation of Gas Exploders for Avalanche Control**

The AXPRO team is currently conducting experimental and numerical studies of the O’BellX Gas Pressure System for Colorado Department of Transportation (CDOT) and Transportation Avalanche Research Pool (TARP). The TARP is a partnership of transportation agencies to further cooperation and research, development, and evaluation of avalanche mitigation equipment and methodology to improve the safety and efficiency of highway transportation in mountain corridors. The TARP was established though a US DOT State Planning and Research pooled fund program and is currently administrated by the CDOT. The main goal is to study the pressure-wave output created by these types of avalanche control devices and compare it with solid explosives. A full scale O’BellX will be installed and tested at the ERL using blast pressure gauges, seismographs, and high-speed imaging. In addition, three dimensional numerical simulations will be conducted and validated using the experimental data. The numerical studies will provide insight about the influence of the topography in the blast propagation. The results of this research will assist CDOT with the implementation of these type of technologies in future locations.

**Conferences**

The AXPRO team was busy during this year with participating in multiples conferences relating to explosive materials. In July 2018, the AXPRO team attended the 43rd International Pyrotechnics Society Seminar in Fort Collins, Colorado. Eduardo Lozano presented a paper on “Modeling Detonation in Non-Ideal Explosives using High-Order Shock Capturing Methods,” and “Gas Explosions with Limited Boundary Conditions and their Effects on DDT”. Additional in January, the paper “Modified Case Charge for Avalanche Control” was published in the International Society of Explosive Engineering in San Antonio, Texas.
From April 11 to 13, Dr. Petr and Cameron Brown attended the National Armaments Consortium General Meeting in Arlington, Virginia. They talked with various government agencies about possible energetics funding proposals from the DOD. AXPRO submitted three white papers jointly with SAS.

Several team members also attended other conferences separately this year. Dr. Petr and Dr. Liu traveled to St. Petersburg, Russia, this summer from May 14 to 18, 2018 to attend the Explosive Welding Conference and the International Symposium on Explosive Production of New Materials: Science, Technology, Business, and Innovations (EPNM-2018). Drs. Petr and Liu each presented a paper at this conference on explosive welding and ANFO.

In June, Dr. Petr visited Sweden with his family, and also attended the Fragblast Conference. It was the 35th year anniversary of this international conference, which is offered every three years in a different continent. This year the conference was hosted at the Lulea University of Technology. Dr. Petr also met with the University of Leoben, Polytechnic in Madrid, and Dr. Alex Spathis who is a former collaborator of Orica, Australia. With AXPRO Dr. Spathis was the sponsor to create Orica chamber at the Edgar Mine. The chamber is currently used for dust explosion by the US Department of Labor Occupational Safety and Health Administration. Dr. Petr was asked to apply to serve on the international organizing committee.

![Dr. Alex Spathis of Orica and his wife enjoying the sunset in Lulea on a boat.](image)

Eduardo Lozano attended the International Detonation Symposium in Cambridge, Maryland from July 16 to 20 in order to develop a deeper understanding of scientific challenges in numerical modeling for non-ideal detonation. Eduardo was able to meet many scientists and discuss this hot topic.

From October 7-12, Dr. Petr left for the International Snow Science Workshop (ISSW) in Innsbruck, Austria. This is the largest snow and avalanche conference in the world and is offered every two years. While he was in Austria, he visited the University of Leoben, and toured the explosive research laboratories and active ore mine with Dr. Thomas Seidel, who organized the event. The University of Leoben will be visiting CSM in April and touring through different mines in the Western part of the United States.
**Students**

*Lea Davis Undergraduate Hire*

New undergraduate AXPRO team member, Lea Davis, from the Chemical Engineering Department. Lea is a Senior from the Explosive Engineering I course, which is offered in the fall. Lea is interested in continuing her education and career opportunities in the explosives field related to military applications. Her research goal is to advance her knowledge about how to make explosive materials safer. Lea will be helping us with current research projects while assisting with our in-house explosives training. Her chemistry background will advance the experience of the team in explosive chemistry.

![Lea Davis in Rocky Mountain National Park summer 2018.](image)

**Eduardo Lozano’s Mechanical Engineering Thermal Fluids Track Ph.D. Progress**

One year after passing the PhD Qualifying Exam, Eduardo made significant progress in his thesis research which will be officially proposed to the Committee on December of this year. His dissertation is focused on the development of a reactive burn detonation model for granular non-ideal explosives (specifically ANFO) using a continuum-level theory and high order shock capturing schemes. The main goal is to predict the influence of the macro-scale heterogeneities in the stability of the detonation wave through different depletion laws. He recently finalized the numerical flow solver for 2-D axisymmetric geometries and is currently working on the addition of multiple materials EoS models.

In addition, Eduardo continues working for the multiple educational and research tasks for AXPRO. Some of them are gaseous detonation characterization for boiler deslagging (Bang&Clean) and avalanche control (O'BellX), as well as teaching assistant for Explosives Engineering I (MNGN 333), Special Explosives Application (MLGN 598) and High-Speed Imaging for Research and Experimentation.

Eduardo will be spending the upcoming Spring semester as a Graduate Research Assistant at Los Alamos National Laboratory. He will work for Dr. Tariq Aslam (T-1 Group) on specialized computational techniques for detonation modeling. These techniques can be directly applied for solving problems using geometrical and asymptotic theories (i.e., Detonation Shock Dynamics (DSD) and Geometrical Shock Dynamics (DSD)), and constitute one of the main aspects of his dissertation research.
**Cameron Brown’s Summer Updates**

Over the summer Cameron and his family visited the land of the conquistadores (Spain). Although Eduardo was unfortunately not in Spain at the same time, Cam had a great vacation exploring Madrid and Barcelona.

Cameron and his family in Spain in summer 2018.

Aside from the family vacation, Cameron continued his thesis research and developed experimental results of 3D-printed solid rocket motor samples using X-ray Photoelectron Spectroscopy. Cameron is excited to potentially present the results at a JANNAF conference this coming December, and to continue developing his energetics research this Fall semester.

**Michael Maestas’ Research at Los Alamos and Master’s Thesis Topic**

Following his first year as a master’s student with AXPRO, Michael worked at Los Alamos National Laboratory for the summer as part of the Applied Engineering Technology Division. He supported a team which provides thermal conditioning capabilities to several of the high explosive shot tests being conducted at LANL. Michael also worked with another team whose research involves embedding instrumentation into...
3D printed parts of various materials. In this research, mock explosive materials will be used such as Plasticine and sugar derivatives. Plasticine is a good mock material for TNT and this will be one of the materials used for the 3D printed plane wave generator. In July, Michael attended the 43rd International Pyrotechnics Symposium in Fort Collins, CO, where a paper on the effects of gas explosions with limited boundary conditions on the deflagration to detonation transition was published. The gas explosions for this research were monitored using high fidelity instrumentation to record pressure and high-speed imaging data. This research was conducted at the Idaho Springs Explosive Research Laboratory. Michael is planning on writing his Master’s thesis on this topic.

![Michael Maestas](image)

_Erika Nieczkoski’s Graduate Research_

Erika Nieczkoski has been enjoying the challenges of graduate school and spent much of the summer conducting research for her graduate degree. She is very excited about the implications of her research in gas explosions towards the energy industry and has really liked learning about topics such as computational fluid dynamics and combustion engineering in her courses.

This Fall semester, Erika will continue her research and coursework with the Materials Science with emphasis in Energetic Materials (Explosives) program.

![Erika with twin sister at the NY State Fair this summer 2018.](image)