

## **Executive Overview – DRAFT**

The Advanced Explosives Processing Research Group (AXPRO) operates within the framework of the Colorado School of Mines (CSM) in Golden, Colorado. AXPRO advances the explosive engineering and science through four core efforts among the different departments, which form the “pillars” that support AXPRO’s purpose:

- a) Research
- b) Teaching
- c) Training and Continuing Education
- d) Industry Consortium

The Mission is to leverage the research, facilities, processes, capabilities, and experience of CSM to assist private industries and the US Government with explosive research, testing, and education.

AXPRO and CSM leadership wish to explore options for expanding their efforts in all four of the core areas through an interdisciplinary program. The group fosters integrative and multidisciplinary research on several areas to address fundamental science and practical challenges involving energetic materials.

We began our explosive engineering research in 2002. For more than a decade, we have been funded from many sources including private industries and the U.S. Government Agencies.

### **Research**

AXPRO is involved in a wide range of research activities. The current research trust is in high fidelity detonation physics and shock wave phenomena in different mediums. Some of our research studies the Equation of State for non-ideal explosives such as Ammonium nitrate and diesel fuel base explosives (ANFO). Detonation of explosives mixtures unconfined allow for transport of detonation energy ahead of the detonation front due to the physical connection between the AN prills. At present, this phenomenon is not well understood. With slowly detonating, non-ideal high explosives systems becoming increasingly prevalent, proper understanding and prediction of the performance of the explosives is desirable.

Current research studies the shock interaction and propagation from different types of explosive sources. The detonation of complex geometrical patterns in a fluid medium generates incident shock waves that interact with each other subsequently generating a shock reflection effect known as Mach reflection. This supersonic fluid dynamics effect is studied through small and large-scale experimental tests and numerical simulations using commercial hydrocodes.

In addition, focal points of our current research include industrial clean up, avalanche control, resource recovery, explosive welding, explosions and material fragmentation, atmospheric charge characterization, initiation system evaluations, physical

characterization of improvised explosive devices, automobile safety igniters, and energetic material properties validation.

AXPRO has a High Fidelity Mobile Detonation Laboratory capable of running full instrumentation and testing of multiple data collection and camera views, the largest of which tests above 100lbs of explosives, conducted remotely in different test sites.

The specialized instrumentation for explosive research include: 4 channel flash X-ray 450KV, 8 channel Photon Doppler Velocimeter (PDV), High Speed and Ultra High Speed Imaging cameras (up to 2 million frames per second), Velocity of Detonation (VOD) instrumentation, fiber optics, piezoelectric gauges, signal conditioning, and delay generating modules. AXPRO operates a small-scale blast chamber and a full high-fidelity mobile detonation physics laboratory (instrumentation and command trailers) for the development of experimental testing in remote locations. Additionally, all the explosives laboratories incorporate a wide variety of initiation and firing systems including: Exploding-Bridgewire (EBW), electric, electronic, shock tube, and remote wireless firing devices.

### **Teaching**

Colorado School of Mines offers internationally recognized, ABET accredited undergraduate and graduate programs in mining engineering and the geosciences. CSM offers a double minor program in explosives engineering and explosive processing to prepare the next generation of explosives engineers. The AXPRO team works closely with the different departments to enhance the explosives minor programs. This collaboration exposes students to cutting edge explosives research currently being conducted by AXPRO and provides students with practical field experience.

### **Training and Continuum Education**

The AXPRO group is dedicated to providing high quality training for professionals in the explosives industry. The Practical Explosive Training course ranges from basic introduction to advanced explosive use. The course is designed to teach proper methods of explosive storage, handling, and use in the State of Colorado. Each session of the course contains a total of 16 hours of classroom and hands-on instruction. The course is designed for new state explosive permit applicants and for current permit-holders seeking renewal.

Additionally, graduate students at the Missouri University of Science and Technology (MS&T) pursuing a Masters or Doctorate Degree in Explosives Engineering may earn credit towards their degree by taking Long Distance Learning Courses that are offered as part of MS&T's collaboration with the Colorado School of Mines. The Advanced Explosives Processing Group at the Colorado School of Mines is excited to be able to offer these specialized courses, which include practical training in industry applications of explosives and experimentation instrumentation methods.

### **Industry Consortium**

AXPRO provides services and technical consulting for domestic and international industries such as mining, oil and gas, and energy. AXPRO offers world-class explosives training for governmental and industrial research groups.

Capabilities include:

- Objective evaluation of industry procedures and development of safety standards and protocols
- Safe integration of government standards for new explosive technologies to private industry
- Detailed investigation of explosives technologies to advance government and industry standards
- Measurement of explosive energy and post-detonation gases
- Experimentation of energetic material performance
- Expertise of ammonium nitrate properties: post detonation properties and physical, chemical, and detonation physics
- Fragmentation studies, using novel methods in a variety of materials
- Environmental studies of blasting effects, including detailed measurements of air overpressure and ground vibration