for the Improvement of Mine Safety and Health, Inc.

Solicitation and Call for Proposals
(AFC518)

TECHNOLOGY DEVELOPMENT GRANTS

Background

The Alpha Foundation for the Improvement of Mine Safety and Health is a private foundation with the mission to improve mine safety and health through funding research and development projects at qualified academic institutions and other not-for-profit organizations. The goal is to address the root causes of disease, injuries, and fatalities in the mining industry and, where possible, to achieve successful implementation of practical solutions derived from the research effort. The Foundation's agenda includes all sectors of mining (coal, metal, and non-metal) as well as both underground and surface mining. Projects supported by the Alpha Foundation must be relevant to the U.S. mining industry and funding is limited to not-for-profit organizations. Information regarding the Foundation's mission and projects that have been funded can be viewed by visiting the Foundation's website at http://www.alpha-foundation.org.

This solicitation is targeting technological developments in which a short-term grant will initially be given to demonstrate proof-of-concept of a proposed technology at the laboratory level. The intent and required outcome for this solicitation is to build some tangible device, instrument or machine as opposed to theoretical research or engineering design that emphasizes process or methods of engineering control. If the proof-of-concept is successful, the grantee will have the opportunity to apply for a second grant for a multi-year effort with significant additional funding to advance the concept to a working prototype and validate its capability through a high fidelity simulated or real operational environment.

The Foundation is allocating $3.5 million for this proof-of-concept technology development solicitation. It is expected that as many as 20 qualified proof-of-concept grants with a maximum funding level of $175,000 per grant and a maximum duration of 18 months will be funded. Significant additional funding, up to $1.5 million per project, will be allocated to fund successful concepts in a second prototype development and demonstration phase.

Solicitation Focus: Proof-of-Concept Technology Developments

Preventing injuries and disease in mining can be achieved in many ways and the Foundation seeks to address all of these methods to work toward achieving its vision of miners in the future being free of work-related injury or disease. Much of the historical improvement in mining health and safety has been achieved from experience-aided engineering that led to increased understanding of the conditions that cause hazardous environments and developing mine design and operating practices to reduce these risks.

Advancements in mechanized extraction and conveying equipment and ground control technologies have led to paradigm changes in mining practices that have dramatically increased productivity as well as improved safety. More recently, other technological advancements, such as proximity detection, have provided additional safeguards to combat new hazards that developed as a result of the increased use of mobile mining equipment. Other recent technology advancements in communication and tracking have enhanced the ability to observe and monitor personnel locations and movements to an unprecedented level. The communication infrastructure also provided a framework to integrate atmospheric monitoring technologies, again to an unprecedented level, thereby providing the opportunity to detect changing environmental conditions and mitigate them before they become hazardous. A continued development of personal protective technologies has reduced injuries to mine workers throughout the industry. In addition to these safety-oriented technologies, advances in dust monitoring and control technologies have also provided significant reductions in exposure, thereby lowering the health risk of developing respiratory disease. In addition, dust and methane control along with advanced ventilation technologies have also worked to prevent explosive conditions from developing. Clearly, advances in technology have played significant roles in enhancing mine safety and health, and the Foundation intends to foster additional technology research with this solicitation.

The technology roadmap is also being aided by unprecedented growth in the connectivity of technologies by developments such as the "internet of things" that enable sensory systems embedded with various control technologies to collect and exchange data. These capabilities enable teleoperation and telepresence to provide the ability to monitor and control distant objects. These proficiencies are creating revolutionary developments in the growth of smart systems and autonomous control. If these approaches can be integrated into the growth of sensory systems now being employed in mining, a new era of risk assessment and intervention can be achieved, which can significantly impact mining health and safety.

It is envisioned that addressing these technology challenges would require a multidiscipline approach involving combinations of expertise in mechanical, electrical, robotics, industrial, hydraulics, structural, chemical, acoustical, control system, manufacturing, and/or systems engineering, depending on the specific technology. It is the hope of the Foundation that this expectation will attract the interest of universities and non-profit organizations beyond the traditional mining community, as well as participation by other departments within universities and not-for-profit organizations that have relied primarily only on the mining engineering expertise in previous Foundation proposals.

Technology Topical Areas

Proposals for a proof-of-concept development for any technology that provides an opportunity to improve mine health and safety is welcomed by the Foundation. It is noted that while "technology" can have a broad meaning, the intent and required outcome for this solicitation is to build some tangible device, instrument or machine as opposed to theoretical research or engineering design that emphasizes process or methods of engineering control. For example, developing a new pillar design formulation would not qualify for consideration as a technology development, but developing an instrument to measure pillar stress that could aid in pillar design formulation would qualify.

While the Foundation has not specifically targeted technology developments in previous funding efforts, there have been a few funded projects that are examples of the types of technology developments that are being sought in this solicitation. Please refer to previous projects AFC113-01, AFC113-10, AFC113-15, and AFC316-42, accessible on the Alpha Foundation website at www.alpha-foundation.org.

The Foundation is particularly, although not exclusively, interested in proposals that address one or more of the following substantive topical areas, for which some additional background is provided after this partial list:

- Explosion Permissible Mobile Vehicles and Platforms
- Remote-Controlled, Autonomous, or Smart Machine Design
- Advanced Personal Protective Equipment (PPE)
- Health-related Monitoring Devices
- Enhanced Environmental and Atmospheric Monitoring Devices
- Atmospheric Purification Technologies
- Geosensing Instrumentation
- Ground Control Technologies
- Non-Destructive Inspection and Testing (NDT) Technologies
- Situational Awareness and Hazard Detection Technologies
- Virtual Reality Solutions

Explosion Permissible Mobile Vehicles and Platforms: A major reason why technology developments in mining, underground coal mining in particular, is more challenging than anywhere else is because they operate in potentially explosive environments due to the embedded methane gas and dusty conditions. Any machine, sensor, or instrument that is used in active areas of an underground (gassy) coal mine must be explosion permissible. As such, the Foundation would welcome any effort to overcome permissibility limitations that are preventing any emerging technology from being implemented in the mining industry.

While MSHA-approved permissible design[1] is the ultimate goal, the Foundation recognizes the difficulty in achieving permissible designs at the concept stage. Therefore, the Foundation in this solicitation is willing to accept the more versatile IEC explosive[2] protection standards if full permissibility as determined by MSHA approval does not appear to be attainable.

The submitter is encouraged to be creative in proposing technological solutions to this topic area, but should provide a clear mission statement and design requirements for the proposed concept. Innovative modes of propulsion and methods of locomotion, including ground traversing and flying are anticipated and acceptable, provided they meet explosion "permissible" design. The proposed size of the mobile unit can vary based on the proposed mission requirement and can range from a self-contained single platform concept to a "micro" robotics concept that might incorporate very small devices that function in some form of hierarchical design. The basic requirement is that it must be able to traverse space in a typical coal mine entry. Designs that can also navigate more extreme conditions that might occur following a mine explosion or collapse will be judged with higher value. Ultimately, the platform must be capable of autonomous or remote-controlled operation, although that function is not required at this stage of the development.

Remote-Controlled, Autonomous, or Smart Machine Design: Machines are an integral element of modern mining. These mining machines are large and powerful and are often used in the extraction and conveying operations. In all cases, there are occupational hazards of various forms associated with the operation of this equipment. Several machines such as continuous miners in underground mining and haulage trucks in surface mining operations are already remotely or semi-autonomously controlled in modern mines. However, other operations with high incidence of injury, such as roof bolting, continue to require direct and full operation by the mine worker. This solicitation topic is targeting technology that promotes removing the mine worker from the operational machinery hazard.

Autonomous machine design provides technology that allows the machine to make decisions and control actions independent of the operator. One of the requirements for a vehicle to move about autonomously is being able to determine its positional coordinates sufficient to provide guidance, navigation, and control of the vehicle within is operational environment. Such technology is now increasing being integrated in the automotive industry and the goal is to bring this technology into mining. This is especially challenging in an underground environment where technologies such as GPS monitoring are non-functional, thereby requiring approaches that are more self-reliant. Underground mining is

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[1] MSHA Document No. ACRI 2001 "Criteria for the Evaluation and Test of Intrinsically Safe Apparatus and Associated Apparatus".

[2] International Electrotechnical Commission (IEC) and the Instrumentation, Systems, and Automation Society (ISA) 60079 standards, Class 1, Zone 1.

also complicated by the vastness of the mine and layout complexity in which a non-uniform checkerboard or other arrangement of tunnels (mine entries) may cover areas as large as a major city.

Beyond using smart technology to control machine operations, the use of the machine to interrogate the mine environment is also an element of consideration for technology development in this topical area. An example of this would be the use of the roof bolter to detect changing conditions or geological anomalies of the surrounding rock mass.

Advanced Personal Protective Equipment (PPE): PPE is a staple of most occupational interventions to reduce injuries to its work force. The mining regulatory body, MSHA, tends to put emphasis and priority on engineering controls, using the logic that the first line of defense should always be used to eliminate the problem at its source. The underlying assumption is that prevention by engineering controls and interventions can fully eliminate the risk. However, there is also no argument against developing and mandating the use of PPE equipment when engineering controls are not fully effective. A prime example of this is the inability of engineering controls to eradicate lung disease (i.e. black lung). Therefore, technologies such as advanced air stream helmets or some form of effective, yet practical, respiratory protective device are the types of technologies that would be relevant under this topic.

Health-related Monitoring Devices: Sensory technologies are being developed at a faster pace than ever before and offer new opportunities to monitor factors that impact the health of the mineworker. Another technology needed to combat the black lung issue is the development of an improved personal dust monitor that can measure and segregate the content of all hazardous dust elements, specifically coal and silica particulates from non-hazardous materials such as rock dust.

A range of other health risks including: nano-sized diesel particulates, operator fatigue, excessive noise exposure, and excessive hand-arm and whole body vibrational exposure are relevant to sensor developments to measure the exposure beyond current capabilities, and provide the framework that will lead to the development of enhanced engineering controls.

Enhanced Environmental and Atmospheric Monitoring Devices: Several factors influence the mine environment and ventilation controls, including airflow, methane emissions, and barometric pressure changes. Atmospheric monitoring capabilities have grown significantly in recent years, but there are remaining challenges that require additional technology developments, particularly when trying to utilize the sensory output to facilitate direct ventilation control. The two primary issues are sensor stability and permissibility. The sensor must exhibit accuracy, repeatability, and stability in regard to confounding factors such as temperature variations that exist in mining environments. The sensors must also be able to operate in an explosive environment when applicable. Developing technologies to provide area-wide sensing instead of point measurements common with current technologies is also needed.

Atmospheric Purification Technologies: Controlling the mine atmosphere is a key element in the prevention of respirable hazards such as black lung, which have claimed the lives of 250,000 coal miners and debilitated hundreds of thousands more. Coal dust is not only a health hazard, but an explosive hazard as well. Gaseous and dusty conditions can create explosive circumstances, which have led to numerous coal mine explosions including the fairly recent incident at the Upper Big Branch mine in 2010 that was the reason for the Foundation's creation.

Controlling airborne dust is challenging and has been the focus of several engineering controls. Dust scrubbing systems have proven to be an effective means of removing dust when it can be channeled into a local area the size of a few cubic feet. As such, scrubbing technologies are generally limited to machine or focused capture efforts, where the dust source is in the immediate vicinity of the scrubbing unit or can be effectively channeled to it by ductwork or ventilation controls. Large area scrubbing is more challenging, but is needed in several mining operations where the dust source is more dispersed. An example of this would be the removal of float coal dust (fine dust particles that are easily dispersed by the ventilation) prior to it leaving the mining extraction area or within the immediate vicinity to prevent it from contaminating the outby areas as it is dispersed by the mine ventilation system.

Geosensing Instrumentation: Mine design is essentially a large-scale structural engineering problem. The key requirements in any structural design are to understand the load conditions, boundary conditions, and material properties. These requirements, along with the ability to monitor the performance of the ground control system, are especially challenging in mining because of the varied nature of the geologic materials and their inherent damage due to the stress conditions resulting from the mining activity. While there are a few devices that have attempted to measure stress directly, most devices use deformation (strain) as a surrogate measure. Required procedures such as over-coring significantly complicate the process. Measurement of triaxial or biaxial stress also complicates the instrumentation. The borehole required for the instrument placement can influence the instrument response and measurement accuracy and reliability, thereby introducing other complicating factors.

The Foundation is seeking creative thinking to propose technologies that provide easier, more precise, and higher quality instrumentation to measure material properties, load conditions, and ground control performance that will facilitate improved mine design practices.

Ground Control Technologies: The development of roof support products with superior performance continues to evolve, primarily being championed by various roof support manufacturers. However, there remains opportunity for innovative technological developments, as the roof support approach has not changed significantly over the past 50 years. Three areas show an obvious need: 1) development of smart support systems such as longwall shields that control behavior (setting pressure) based on loading, 2) mobile roof support concepts for gateroad standing support that replace the practice of supporting the entire gateroad when only the abutment zone requires additional support, and 3) smart materials that that can be engineered to provide specific but unusual material properties that can overcome what is normally conflicting responses, such as high stiffness and large yield or a pumpable cementitous material that will yield plastically rather than exhibit brittle failure.

Non-Destructive Inspection and Testing (NDT) Technologies: Non-destructive inspection and testing to evaluate the properties of a material, component or system of critical importance without causing damage is increasingly being utilized in various industries outside of mining. The intent of this focus area is to provide such technologies to a specific mining application. For example, installed seals are critical structures in the control of mine explosions in mined-out areas by preventing them from propagating into active working areas. The current practice to evaluate installed seal integrity is by penetrometer probing (up to one inch) of the seal skin as a surrogate measure of the material strength. Recognizing that this procedure inadequately evaluates the full seal structure, alternative technologies and procedures need to be developed for non-destructive testing of installed seals.

Non-destructive testing technologies might also provide a means to assess geological conditions as well. This is particularly challenging because the rock mass is typically already damaged but being able to assess a change in behavior would provide a hazard assessment capability that would be extremely beneficial in mining. Such capability overlaps into providing situational awareness, which is the next topic.

Situational Awareness and Hazard Detection Technologies: Situational awareness is an important aspect of safety in any occupation, but is amplified in mining, where as in the case of underground mining it is dark with limited lighting, the working space is restrictive, the environment can be noisy and dusty, and large mobile machinery is constantly in motion in the active work areas. Likewise in surface mining, the equipment is so large that visibility alone can be an influential factor in situational awareness. Within this context, there are numerous opportunities for technology advancements to improve situational awareness including: more robust (non-magnetic) proximity detection, real time (observational) ground stability, detection of energy states of equipment and achieving automatic lock out or de-energizing prior to performing maintenance.

Virtual Reality Solutions: Virtual reality is an emerging technology that is literally changing how we see the world. Being able to realistically visualize conditions and situations provides an element of unprecedented simulation of events that have far reaching impact in training, planning, and decision-making. *Note that the emphasis in this topic is on the development of new technologies or innovative applications that can directly enhance safety.* While training is often the end user of virtual reality technologies, training in itself <u>does not qualify</u> for consideration in this solicitation.

The submitter is encouraged to be creative in applying virtual reality technology for in mine use as well as to enhance design and compare engineering alternatives to enhance health and safety rather than the training classroom. As an example, a virtual reality headset might be developed that would enable a miner to "see through" a smoke-filled escapeway when worn during escape.

Intellectual Property and Technology Commercialization

The ultimate desired outcome from this effort is the commercial readiness of new technologies that can significantly impact the health and safety of the nation's miners. The Foundation's standard policy regarding intellectual property is as follows:

> *Ownership of works first produced in the performance of this Agreement shall be owned by the Grantee. However, the Grantee provides to the Foundation a non-exclusive, irrevocable, and royalty-free license to reproduce, publish, distribute, create derivative works, and otherwise use the works by or on behalf of the Foundation for educational and/or research purposes.*

In the case of new technology developments resulting from these grant agreements, the Foundation expects that the Grantee will not inhibit the commercialization effort, but rather seek opportunities beyond the grant with private sector entities to pursue commercialization of any viable technologies.

Eligibility Criteria and Limitations

Concept proposals will be accepted only from U.S.-based academic institutions and not-for-profit organizations qualifying as exempt from taxation under the Internal Revenue Code.

In addition:

- The requirement is for the not-for-profit entity to perform the development of the proposed technology. However, private sector partnerships can be used in an advisory council approach to provide guidance on the technology development and use of specialized facilities or laboratories for testing on a procured basis.

- It is Foundation policy that grant funds may not be used to support clinical trials of unapproved drugs, to construct or renovate facilities, for lobbying, for political activities, or as a substitute for funds currently being used to support similar activities.

Preparing the Proof-of-Concept Proposal

The proposal should clearly identify the proposed technology, relate it to one of the technology areas listed previously in this solicitation or provide a suitable alternative category, and formulate a proof-of-concept effort relative to the specified technology. The requirement of this proof-of-concept effort is to confirm the basic functionality of the concept. The use of scaled and/or *ad hoc* components is acceptable. The components do not need to be fully integrated to demonstrate the proof-of-concept. The accompanying demonstration of the concept only needs to be at the laboratory level and can be experimental in nature. The Proof of Concept proposal must also identify the anticipated endpoint of the proposed technology development if granted follow-up funding. It is noted this information will be considered as preliminary and will be used to provide insight into the perceived maturity and commercialization potential for the proposed technology.

The proof-of-concept submittal will be considered a full proposal and will be used to determine awards for the proof-of-concept funding phase.

The proposal requirements and format, which are outlined below, should be strictly followed. Other than the concept summary, there are no section limitations regarding length, but the overall proposal should not exceed 25 pages in length, excluding the cover page.

Cover Page: A separate single cover page shall be labeled "Proof-of-Concept Technology Development Proposal for the Alpha Foundation for the Improvement of Mine Safety and Health, AFC518". It shall include the following information and must be signed by an authorized officer.

Title: Descriptive title of proposed work
Submitting Organization: Name and address of organization
Principal Investigator: Name and contact information (phone and email)
Administrative Contact: Name and contact information (phone and email)
Research Approach and Focus Area: Selected from areas designated in the solicitation or another with importance to miner safety and health
Estimated Cost: Estimate of total project cost
Period of Performance: Estimate of time required to complete the research

Concept Summary: Provide a single page describing the proposed concept and how it will address the technology development challenge of this solicitation. Include a statement of the expected outcome at the end of the Proof-of-Concept phase, and anticipated endpoint for development of a working prototype of the concept should additional funding be provided.

Background Information: This section shall provide the necessary background information to justify the relationship of the proposed concept to the solicitation agenda and that the proposed effort represents a new approach.

Topical Area Discussion: Discuss how the proposed technology is relevant to the selected topical area or an alternative area with well documented importance to protection of miner health and safety and its relationship to addressing a particular mining health and safety issue.

Assessment of Previous Technology Efforts: The proposal should discuss previous technological efforts that have been exploited in this area and analyze the proposed technology relative to the prior art.

Concept Formulation and Mission Requirements: The proposed concept is to be formulated and its mission requirements explained in this section. Formulation of the concept should address the following topics.

Mission Statement: Provide a specific mission statement for the proposed technology. What are its goals, planned operational parameters, and likely limitations?

Design Strategy: The proposed concept should identify the design strategy relative to the mission requirements. The strategy should explain the overall technology design and address the functionality of the concept rather than the detailed intricacies of the specific components. In other words, how will the proposed design address the technology challenge and achieve the mission requirements?

Rationale for your concept: Explain why this approach was selected. Discuss the benefits of this approach over what has been done previously with other competing technologies or engineering efforts.

Technology Components and Proof-of-Concept Demonstration Plan: The purpose of this section is to describe the specifics of the proposed technology components and how these elements will be demonstrated to establish a proof-of-concept.

Overview of the Technology System: Describe whether the proof-of-concept plan will be at the system level or component level and whether the components will include ad hoc *elements or actual components that will likely be included in a potential working prototype design.*

Description of Technology Components: Describe the components of the proposed technology to be used in the proof-of-concept effort. Are these components readily available? What level of development is needed for critical elements of the proposed technology? Describe the level of integration of components that will be included in the proof-of-concept demonstration.

Facilities and Laboratory Requirements: Describe the facilities and laboratories to which you have access that will be utilized in the proof-of-concept development and validation testing.

Proof-of-Concept Demonstration: As previously noted, the requirement for proof-of-concept validation is demonstration only at the laboratory level. As such, provide a description of how the concept will be validated to establish the proof-of-concept. This discussion should address the test protocol relative to the design strategy and mission statement for the proposed technology. The test objectives and the metrics that will be used to judge a successful outcome should be clearly identified.

Human Subjects: If the proposed research will involve any human subjects the proposal must describe the steps that will be taken to ensure human subject protection.

Preliminary Prototype Developmental Plan: As noted previously, if the proposed proof-of-concept proves promising, you may be invited to propose a plan to advance the proof-of-concept to some level of a fully functional working prototype that will be demonstrated in a real or simulated operational environment. Provide a statement of your anticipated endpoint of the proposed technology development if granted follow-up funding. You may use existing frameworks such as the Technology Readiness Level (TRL)[3] if you choose. This information will be useful in providing some insight into the potential viability and commercial potential of the proposed concept.

Staff Expertise in Technology Development and Mining Knowledge: Discuss the expertise of the PI and other key personnel relevant to the selected area. Document and discuss previous experience in technology development, making note of any previous research or endeavor that is relevant to this topic and highlight any effort that is directly related. Discuss the staff's working knowledge of mining and/or how this knowledge will be provided and used in guiding the development of the technology. A CV, not to exceed 1 page in length each, may be submitted for the PI and other key personnel. Please note that the CVs will not count against the 25-page proposal limit.

Partnerships: Identify any partnerships and their role in strengthening the research team or facilities to achieve a more successful outcome.

Letters of commitment: Attach all letters of commitment with mining companies and any other partners or stakeholders whose cooperation or participation is necessary to complete the project.

Budget: A maximum budget of $175,000 is available for proof-of-concept projects. Provide estimates of the following:

- **Salary**: Provide costs for proposed personnel
- **Travel**: Itemize travel requests, including the purpose of each trip
- **Supplies**: Estimate overall cost of supplies
- **Equipment**: Itemize major equipment needs including computers and software
- **Contractual**: Estimate the cost of all external contracts if applicable.
- **Other**: Itemize any other expenses by category and unit cost.
- **Indirect**: The Alpha Foundation limit on indirect costs is 20%

Project Schedule and Decision Points: The allowable timeframe for proof-of-concept projects is up to 18 months from project start. The major elements of the project effort are

[3] https://en.wikipedia.org/wiki/**Technology_readiness_level**

to: 1) finalize the design, 2) fabricate and/or assemble the technology, and 3) conduct proof-of-concept testing. The timeline for each of these elements should be identified and will provide the basis for decision points for assessing project performance. Interim reports will be required at 6-month intervals in the project.

Deliverables: The deliverable for the project will be the proof-of-concept technology. Since there may be opportunity for follow-up funding, the disposition of the deliverable will be decided following completion of the project.

How to Submit a Proposal

Proposals must be prepared in Adobe pdf format and adhere to the format provided above. The proposals must be submitted through the Alpha Foundation Grant Management System, which can be accessed at https://glenmede.smartsimple.com/welcome/alpha. The submission deadline for this solicitation is 5 pm Eastern Time on April 28, 2017 Any proposal, modification, or revision received after the exact time specified is "late" and will not be considered.

Disclaimer Notification: The Foundation is not responsible for the content or correctness of materials supplied in response to its solicitations and generally and specifically disclaims any responsibility for the same. Proposers are expected to appropriately mark each page of their submission that contains proprietary information. The Foundation will exercise reasonable care in protecting proprietary information from unauthorized disclosure.

Questions regarding the submission of the Concept Proposals can be addressed to grants@alpha-foundation.org.

Funding Decisions and Notifications

The concept proposals will be reviewed and those judged to have a viable design and provide a well-conceived approach will be awarded funding to demonstrate proof of concept of the proposed technology. Selected grantees notified on or about June 15, 2017.

Organizations, which complete successful proof-of-concept developments, will be considered as contenders to apply for further funding, which is anticipated to be as much as $1.5 million per project. Those selected for consideration will be required to submit a **Prototype Development and Validation** proposal which will detail the planned level of technology development and validation effort consistent with the validation guidelines. These proposals will be technically reviewed and those that are selected will be awarded a new grant and additional funding.