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To The Subcommittee on Energy and Mineral Resources
U.S. House of Representatives

An Oversight Hearing on "Exploring 21st Century Mining Safety, Environmental Control, and Technological Innovation."

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Chairman Lamborn, members of the Subcommittee. My name is Jim Kuipers and I am a consulting mining engineer based in Montana. Thank you for inviting me to testify on the important subject of modern mining safety, environmental controls, and technological innovation, three subjects that have been very important factors in my career, and to mining and society in general.

Professional Background and Affiliation

I was raised in a mining family and attended Montana School of Mines, obtaining a B.S. degree in Mineral Process Engineering in 1983. I am presently a mining environmental consultant, and the principal consulting engineer with Kuipers and Associates, based in Montana. I am a registered professional engineer in Colorado and Montana. I have worked on mining and environmental projects including engineering design, permitting, operations, reclamation and closure, water treatment and financial assurance for more than 30 years. Since 1996, my primary work has been as a consultant providing engineering and other technical expertise to governmental and non-governmental organizations relative to hardrock mining.

I am presently involved in providing technical assistance to the U.S. EPA, several tribal and state/provincial governments, and non-governmental clients on matters related to the subject of this hearing. However, the subject matter of my testimony will focus on the larger picture of my professional experience and opinions developed therefrom on the subjects of modern mining safety, environmental control, and technological innovation.

Introduction/Overview

I would first like to bring some perspective to the subject matter by first discussing the past and then the present status of the mining industry with regards to the subject matter.

In 1553 the masterpiece *De Re Metallica* (of Metal Matters) by Georgius Agricola was published in which he described the state of mining safety, environmental controls and technological innovation of the time. It was translated, with extensive technical and historical notes, in 1912, by a young American mining engineer and his Latin-linguist-trained wife. Their names were Herbert Clark and Lou Henry Hoover, whom you all know as our 31st President of the United States and his first lady.

With respect to mining safety, Agricola said: "*It remains for me to speak about the ailments and accidents of miners, and of the methods by which they can guard against these, for we should always devote more care to maintaining our health, that we may freely perform our bodily functions, than to making profits.*" The measures he recommended included providing miners with protective clothing; he was aware of the hazards of mining and respiratory disease; and, advocated that miners should not work two shifts per day because of increased risk of injury.

He also recognized the environmental impacts of mining in writing "*And when the woods and groves are felled, then are exterminated the beasts and birds, very many of which furnish a pleasant and agreeable food for man. Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away.*

Therefore the inhabitants of these regions … find great difficulty in procuring the necessities of life …"

And, he recognized the importance of technological innovation in the following frequently quoted passage:

> *"Furthermore, there are many arts and sciences of which the miner should not be ignorant. First there is Philosophy, that he may discern the origin, cause, and nature of subterranean things, for then he will be able to dig out the veins easily and advantageously… Secondly, there is Medicine, that he may be able to look after his diggers and workmen…, that he himself may be able to heal them or may see that doctors do so. Thirdly, to follow Astronomy, that he may … judge the direction of the veins. Fourthly, there is the science of Surveying that he may be able to estimate how deep a shaft should be sunk to reach the tunnel which is being driven to it … Fifthly, his knowledge of Arithmetical Science should be such that he may calculate the cost to be incurred in the machinery and the working of the mine. Sixthly, his learning must comprise Architecture, that he himself may construct the various machines and timber work required underground. Next, he must have knowledge of Drawing, that he can draw plans of his machinery. Lastly, there is the Law, especially that dealing with metals, that he may claim his own rights…, that he may not take another man's property…, and that he may fulfill his obligations to others according to the law"*

I want to be one of the first to make the suggestion that a great deal has changed since the 15th century in terms of these issues, but at the same time remind you that they are still extremely pertinent and unresolved. The period of my personal career in mining, from 1972 when I first assisted my grandfather as a small miner to the present as an industry iconoclast, serves as a good measure of that progress as well as the challenges that remain for the 21st century and beyond.

Mining safety is a subject of particular interest and importance and I am glad to see it as the first subject, as the health and welfare of the people who work to produce metals and energy related minerals should be of paramount importance. My career span begins with that of being a 12-year old boy assisting his grandfather one summer exploring for gold and silver and collaring his first underground mine adit. My grandfather's formal training in mining sprang from the 1930's when he made his first fortune and immediately switched to construction contracting to make a living and then retired before resuming life as a small miner in the early 1970's when I joined him. I learned to drill, blast and muck as well as some bad habits as safety was an afterthought, which is why such endeavors would be deemed illegal in most developed nations today.

In 1973, the Secretary of the Interior, through administrative action, created the Mining Enforcement and Safety Administration (MESA) as a new departmental agency separate from the Bureau of Mines. MESA assumed the safety and health enforcement functions formerly carried out by the Bureau to avoid any appearance of a conflict of interest between the enforcement of mine safety and health standards and the Bureau's responsibilities for mineral resource development. Next, Congress passed the Federal Mine Safety and Health Act of 1977 (Mine Act), the legislation which currently governs MSHA's activities. The Mine Act amended the 1969 Coal Act in a number of significant ways, and consolidated all federal health and safety regulations of the mining industry, coal as well as non-coal mining, under a single statutory scheme. The Mine Act strengthened and expanded the rights of miners, and enhanced the protection of miners from retaliation for exercising such rights. Mining fatalities dropped sharply under the Mine Act from 272 in 1977 to 86 in 2000. The Mine Act also transferred responsibility for carrying out its mandates from the Department of the Interior to the Department of Labor, and named the new agency the Mine Safety and Health Administration (MSHA). (from http://arlweb.msha.gov/MSHAINFO/MSHAINF2.htm).

In 1983, when I began my professional career in the mining industry, implementation of MSHA was relatively new and the mining industry focus was primarily on achieving compliance, mostly in terms of avoiding fines, and not necessarily on achieving a zero fatality and by no means a zero lost-time or much less a zero reportable accident rate. The Safety First movement in industry and government began in the United States in the early 1900's and has shown significant reductions in both accidents and fatalities, leading to a record low number of fatalities in 2015. However, while we all continue to celebrate the technologically amazing feats that led to the successful rescue of 27 miners in Chile in October 2010, we need to be reminded that in the same week 37 miners died in a Chinese mine and a month later in New Zealand 29 coal miners died in a series of explosions. And all of this took place just after April 5, 2010 when 29 miners were killed at the Upper Big Branch mine in West Virginia in an explosion resulting in the worst mine disaster in the U.S. since the 1960's.

My own path to my current career has also been marked by mine safety issues. This has ranged from observing unsafe worker conditions in a variety of manners, particularly at smaller mining and mineral processing operations, to seeing exposure of workers to arsenic and other toxic substances, to being complicit as a manager in two worker fatalities that it was within my power if not my responsibility to prevent. But in both cases, despite carrying out the level of safety programs at the time, it was not corporate policy to encourage or allow the exercise of those powers. Fortunately, times have continued to change for the better in this regard as I will discuss later.

Environmental control development to present has been encouraged if not required by both lawsuits and regulations such as the Clean Water Act, the Surface Mining Control and Reclamation Act (SMCRA) and the Comprehensive Environmental Remediation, Cleanup and Liability Act (CERCLA). I am a native of Butte, Montana, home of the largest Superfund site in the U.S. spanning the Upper Clark Fork River basin, where over 150 years of mining history on a major scale has occurred and continues. The first substantive environmental controls for mining pollution in the U.S. were adopted at the Anaconda Smelter following lawsuits by local farmers and ranchers whose crops and livestock had been affected by emissions from the then state-of-the-art smelter in the early 1900's. In the 1960's a large wetlands and pond catchment called Warm Springs Ponds was constructed to address the largely uncontrolled discharges of waste rock, tailings and other mining wastes from the mining operations that were causing acid rock drainage and metal to enter and render "biologically lifeless" the streams and rivers located in the area. And with the listing of the Butte-Silver Bow, Anaconda, and Milltown-Clark Fork River sites in the basin in 1983, began the long process that continues today of applying, and in some cases developing, environmental control technologies for mine features including open pits, underground mines, waste rock, tailings, leach piles and more. This has included source control technologies involving reshaping, covering and revegetation; engineered liners and covers for waste repositories; stormwater diversions and catchments and treatment if necessary; a host of physical, biological and chemical water treatment methods ranging from passive to complex active processes that ultimately have proven capable of meeting any water treatment requirement, albeit at a cost.

While we have developed the means necessary to control mining pollution to a great extent, two factors have become evident. First, to a great extent the industry is only willing to apply those technologies if they are required by regulation, and second, the assumption that the technologies are infallible or will always work as intended is unwarranted. The most common example is that of mining solution liners. The fact is, liners always leak. The obvious answer to this dilemma is to incorporate a redundant double-lined system that incorporates a leak detection and removal system within the two liners, thus removing any leakage from the first liner before it can create head and leak through the second. However, this approach has yet to be incorporated universally where practical and the result is hundreds of liner systems have been installed with unknown seepage rates throughout the U.S. – where these are located away from water resources they may not be a problem, but many will as we experience the actual efficacy of the systems over time.

Technological innovation has been a hallmark of the last century to the present. It is one of the reasons I truly believe we should be optimistic for the future. However, it also offers a great deal of cautionary wisdom in terms of lessons from the past half-century. The major technological innovation in the mining industry has been that of technologies such as open pit mining and cyanide leach technologies that rendered previously uneconomic and previously unmined low-grade ores profitable. The result was the development of enormous open pits, waste rock piles, heap leach and tailings piles in a surge of mining that took place beginning in the 1960's, was subject to a few booms and busts and continues to this day. In some places such as Montana, the public decided in a referendum to ban open pit and cyanide leach practices in response to those practices, resulting in both discharges as well as significant public financial liability. Today, the question of coal mining is receiving similar attention in the U.S.

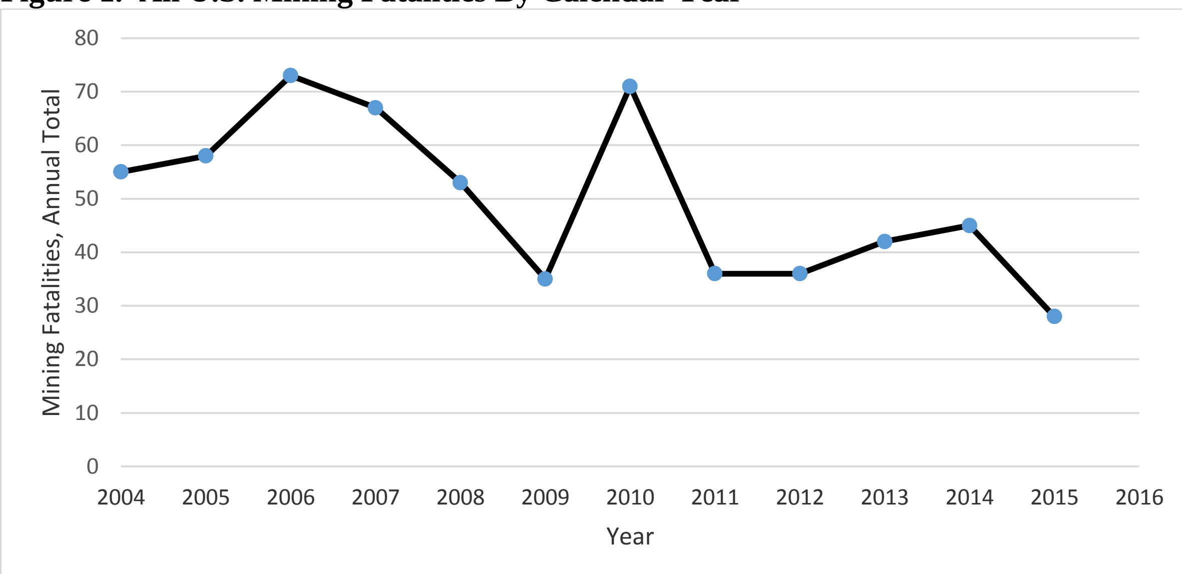
It has become clear to me that the questions of science, technology and ethics, that first intrigued me when I was attending the Montana School of Mines in the 1970's, have always been and continue to be extremely relevant to mining engineers and others involved in technological innovation as it relates to issues such as mining safety and environmental control. I am fortunate to have been a part of developing and implementing the Good Neighbor Agreement[1] between Stillwater Mining Company and Northern Plains Resource Councils over the past 18 years. A key part of the agreement is the development, evaluation and implementation of modern technologies to address water quality and other issues. The requirements of the agreement and interaction of the parties to raise, discuss and ultimately resolve the issues of mining in a "last best place" has given me a chance to be part of an intimate and prolonged discussion of technological innovation as it relates to mining, and both the societal rewards and challenges particular to it as we go forward.

[1] https://www.northernplains.org/issues/good-neighbor-agreement/

The 21st Century – where should we go?

Mine safety has made significant progress however it appears that those efforts have reached a plateau, and the industry is still a significant distance way from meeting the goal of zero fatalities. As shown in Figure 1, during the past 10 years the number of fatalities at all mining facilities in the U.S. have ranged from a high of 71 to a low of 28 achieved in 2015, which sets the current record for the lowest number of mine fatalities recorded for any year in the U.S. While 2015 sets a milestone, it may be more a matter of both luck and economic circumstances resulting in less hours worked, and by no means should be seen as indicative of a further trend downward without further evidence.

Figure 1. All U.S. Mining Fatalities By Calendar Year[2]



In order to identify what it will take to achieve the mining industry's stated goal of zero fatalities, industry leaders, labor, regulators, policy makers and others will need to come together to make further changes to the current strategies. And while current industry initiatives such as CORESafety should be embraced, a health and safety framework such as that recommended by the National Mining Association[3], that relies solely on an industry management system approach to improve health and safety by itself, is inadequate. In order to be effective industry initiatives must be accompanied by a strengthened and more effective enforcement system that includes inspections and fines, as well as the potential for mine closure if circumstances warrant. We need to remember that the mining industry is still highly diverse, and while many in industry are embracing change, the industry is still highly influenced and in particular some mines are still operated by those who do not share what should be an absolute view in terms of the goal of zero fatalities.

An excellent, well-thought out and progressive approach to mine safety standards that should become policy are contained in the Initiative for Responsible Mining Assurance (IRMA)

[2] Data source http://arlweb.msha.gov/stats/charts/allstates.pdf
[3] Watzman and Popovich, *The Time Is Right for a New Mine Safety Paradigm*, February 21, 2014, Coal Age.

Standard.[4] The IRMA standard is being created by a multi-stakeholder group and is an independently verifiable responsible mining assurance system that improves social and environmental performance. IRMA's vision is that of a world in which the mining industry respects human rights and the aspirations of affected communities; provides safe, healthy and respectful workplaces; avoids or minimizes harm to the environment; and leaves positive legacies.

The IRMA Standard specifically addresses mining industry occupational health and safety and sets out international standards with respect to mine-related safety and health inspections, accident reporting, investigation, training, hazard assessment and management, and workers' rights to participate in workplace health and safety decisions, be adequately trained in their tasks, be informed of occupational hazards, and remove themselves from dangerous workplace situations. The objective is to identify and avoid or mitigate occupational health and safety hazards; maintain working environments that protect workers' health and working capacity; and promote workplace safety and health. It contains requirements for: health and safety risk assessment and management; communication and engagement with workers and others; measures to protect workers; inspections, monitoring and investigations; and health and safety data management and access to information.

Environmental control technologies are presently available to reduce or minimize the impacts from acid drainage and metals leaching, however in order to do so they must be conservatively applied, designed appropriately, carefully implemented, and dependably maintained and operated for as long as necessary. Some state regulations such as New Mexico's Mining Act, even go so far as to suggest that the analysis must predict no long-term operations and maintenance such as water treatment. Others have suggested that there should be a ban on mines that require water treatment.

Too often, operators produce inappropriate, inadequate, and overly optimistic predictions in their water quality models. Rather than use available science to make conservative and more accurate predictions, the industry's overly optimistic predictions result in few applications and/or improvements in environmental control technologies and technological innovations. I first documented in 2006[5] this pattern of inaccurate water quality predictions resulting in discharges to groundwater and surface water requiring reactive rather than pro-active mitigation measures. Lawmakers, regulators, and the industry should take a conservative approach in the identification of mitigation measures to ensure the vast majority, if not all mine sites, do not ever result in avoidable discharges to the environment.

Some regulations are inconsistent with modern practice. An example is the Clean Water Act allowing mining companies to treat toxic mine waste as "fill" material and designate our lakes, rivers, and streams as "waste treatment systems". Another loophole allows mine developers to designate natural lakes, rivers, streams, and wetlands as "waste treatment systems," exempt from the Clean Water Act. The current rule-making defining waters of the United States did not include any change to this exemption, despite this being a clear example of failure to use modern

[4] http://www.responsiblemining.net/

[5] *Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements*, 2006. https://www.earthworksaction.org/library/

environmental controls which would restrict or prevent the discharge of mine waste directly into wetlands, lakes, rivers, and streams.

Mining by its nature will always be a dirty business with all the inherent risks involved in the extraction of metals and minerals from the earth. I was reminded of this when I served as the engineering liaison to the Mt Polley Expert Review Panel for the two First Nations in Canada most directly affected by the catastrophic failure of the Mt Polley tailings facility. Since then, I have been involved in developing and implementing regulations at mine sites in Montana and elsewhere to address the risk of catastrophic and more common failures. This was made all the more poignant by the more recent and even more catastrophic failure of the tailings dam at the Samarco mine in Brazil that resulted in numerous casualties and untold damage to the economy and environment.

The Mt Polley Panel consisted of three of the foremost experts recognized by industry and their recommendations spoke directly to both Best Available Tailings Technology but also Best Applicable Practices. We recommend creating a national policy to implement the recommendations of the Independent Expert Engineering and Review Panel, Report on Mount Polley Tailings Storage Facility Breach.[6] These include:

- Creating an independent tailings review board (ITRB) to evaluate tailings dam designs.
- Using Best Available Technology (BAT) that fundamentally shifts tailings storage away from tailings ponds that store water to filtered (aka dry) tailings, as well as:
  - Eliminate surface water from the impoundment,
  - Promote unsaturated conditions in the tailings with drainage provisions, and
  - Achieve dilatant conditions throughout the tailings deposit by compaction.
- Evaluating tailings dam designs for these potential failure modes:
  - Undrained shear failure for dams with silt and clay foundation soils.
  - Water balance adequacy, including provisions and contingencies for wet years.
  - Filter adequacy, especially for dams containing broadly graded soils or mine waste.
- Applying design, construction and safety standards developed specifically for tailings dams, rather than adapting those used for water retention dams.

My home state of Montana would serve as a good starting place for these recommendations. I participated with the Montana mining industry and mining association together with members of the panel, to develop *Montana SB0409, An Act Revising Metal Mine Reclamation Laws; Establishing Standards for Tailings Storage Facilities; Establishing a Fee, Defining Terms, Creating Independent Review Panels; Providing for Review and Inspections, Providing Enforcement et al.*[7]

My own experience is that while we have the environmental control technologies necessary to address mining pollution, we have yet to recognize that effective control requires a philosophy just as much as the technology to accomplish the job. This is where the adoption of risk

[6] https://www.mountpolleyreviewpanel.ca/final-report
[7] http://leg.mt.gov/bills/2015/sb0499/SB0409_1.pdf

assessment and management processes becomes extremely important as we go forward. My recommendation is for a combination of processes to be used involving Failure Modes and Effects Analysis (FMEA) and Adaptive Management Planning (AMP).

FMEA is a methodology for the assessment of 'risk', which is a combination of likelihood and consequences of failure. The goal is to provide a useful analysis technique that can be used to assess the potential for, or likelihood of, failure of structures, equipment or processes and the effects of such failures on the larger systems, of which they form a part, and on the surrounding ecosystem, including human health and safety. Mining companies frequently use this assessment method to evaluate the risk that their proposed project as well as reclamation and mitigation measures impose on the surrounding environment, workers and the public. The FMEA provides the evaluators with the ability to perform a systematic and comprehensive evaluation of potential failure modes of the design/plan in order to identify the potential hazards.

The FMEA is typically supplemented by the preparation and inclusion of an AMP to address the water resource and other environmental and social issues identified in the plan, and to address the potential for greater than predicted impacts in terms of both operational and long-term issues and propose and determine, in a proactive manner, mitigation measures that would be effective to address those issues. The AMP should consider potential failure modes and effects and ensure that contingency measures are identified and implementable in the event they become necessary. The plan should have a clear and detailed process linking monitoring with on-the-ground actions and regulatory enforcement.

According to the industry's *Global Acid Rock Drainage Guide*[8], FMEA is a method that is widely used for reliability analysis of systems, subsystems, and individual components of systems. FMEA provides a mechanism to identify the multiple paths of system failures. A prerequisite for an effective FMEA is to address "all conceivable failure modes of a system." A team of cross-disciplinary experts representing multiple stakeholders including the local community is required to conduct an effective FMEA. The FMEA process for mining projects is described by Robertson and Shaw[9]. Vick[10]provides an experienced perspective on the use and abuse of risk analysis using the FMEA method.

However, even with the development of all of these environmental control practices, we lack basic policy protections to ensure mining companies carry out those practices. Thus, an update to our mining regulations creating modern performance, reclamation, and enforcement standards is urgently needed. Neither the current Bureau of Land Management (BLM) 43 CFR Part 3809 nor the Forest Service 36 CFR Part 228 regulations require hardrock mine operators to use proven, economically achievable, technology standards to ensure that mines operators reclaim mines in a manner that protects water resources, fish, and wildlife.

Technology standards have been a staple in modern environmental protection for over 40 years. The Clean Water Act, Clean Air Act, and the Surface Mining Control and Reclamation Act

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[8] The International Network for Acid Prevention (INAP), 2013. http://www.gardguide.com
[9] *Failure Modes Effects Analysis*, 2006 http://www.fmeainfocentre.com
[10] http://www.infomine.com/library/publications/docs/Vick2014.pdf

(SMCRA) governing coal mining, each use technology standards that form the basis for the protection of our communities and natural resources. BLM and the Forest Service should use similar standards to protect public resources from the impacts of hardrock mining that include:

- Technology-based standards for environmental controls appropriate to the conduct of hardrock mining, including incorporating the recommendations of the Independent Expert Engineering and Review Panel, Report on Mount Polley Tailings Storage Facility Breach report

- Detailed performance standards for hardrock mining operations. Miners should meet strict, Best Available Tailings Technology and Best Applicable Practices operating standards throughout the life-cycle of the mine – from exploration through to closure. The requirement to meet these standards will protect pre-mining water quality and water, as well as fish, flora and wildlife. In particular, these standards must prevent surface and groundwater contamination by mining influenced water such as acid mine drainage and toxic substances used in mining. Mines must minimize disturbance to fish, wildlife, flora, and vegetation to the greatest extent possible. To facilitate mine planning and to guide reclamation, operations must submit detailed, pre-mining baseline information on hydrology, water quality, geochemistry and the flora and fauna residing within the potentially impacted ecosystem. Monitoring should continue throughout the mine life-cycle including during active operations and post-reclamation for as long as necessary to ensure long-term effectiveness of the environmental control measures either relied upon, such as in the case of predictions, or installed, such as the use of various types of covers or passive water treatment operations.

- Enforcement system with teeth. A revised enforcement system will "block" bad environmental actors from obtaining approval for mining, provide for regular inspections of mining operations, and impose penalties on miners who violate regulatory requirements. It will also allow citizens to enforce environmental regulations on mines through citizen suits. These measures are necessary to deter mine operators from violating environmental requirements, and to detect environmental violations and risks in a timely manner.

- A system of fees charged to mine operators to defray the necessary costs of inspections, environmental reviews, and other administrative functions under a new regulatory program. A new fees system placing this program on a "pay as you go" basis would allow BLM and the Forest Service to secure needed funding for more mine inspections. This system will insulate the BLM and Forest Service mining regulatory programs from sequestration and other budget cuts that threaten effectiveness. A fee system would also safeguard against conflicts of interest inherent in the environmental review of proposed mining projects.

Technological innovation, building on our recent history of the last century, holds great promise and opportunity for the 21st century. Some of the key opportunities that should be addressed include:

- Robotic mining and phasing labor to more technology related aspects
- Further innovations in water treatment including metals recovery/re-use
- Beneficial use of mine waste rock and tailings where appropriate
- Technologies to address acid drainage and metals leaching at the source
- Improvement in the evaluation and reliability of passive treatment systems

However, at the same time, the concerns of technology and ethics from my college years have become more pronounced rather than less. In many respects never has there been a more exciting time given the frontiers of genetics, medicine, physics, biochemical engineering as well as a host of others that are being and have yet to be explored, and in the same manner for the mining industry with respect to both safety and environmental control. At the same time, there are a host of ethical dilemmas we must face as both society, and thus our reality, inevitably continue to change. Indeed, for technological innovation to take place we must acknowledge that the present is changed from the past, and look to the future of resource extraction.

I am in the thick of a number of hardrock mining projects either ongoing or being proposed in the U.S. and Canada as well as elsewhere. Two key areas have emerged from that involvement that will have to be addressed related to technological innovation.

The first is that there is an expectation if not requirement for conservative assessment of potential impacts. This should result in the voluntary inclusion and implementation of progressive pollution controls including, advanced water treatment, liners and seepage collection systems under all pollution sources including waste rock, and smelting emissions controls that make them a model of what can be accomplished with modern mining technology. We should go beyond tailings and ensure that in every aspect of mining technology and practice "best" is the standard rather than continue to argue for anything less just because it's cheaper. And as the recent catastrophic events and continued fatalities in the mining industry should serve as a constant reminder, we need to remember the efforts towards "continual improvement" that are critical to our success.

The second and in fact much more difficult issue is that of "place." Even if we could mine hardrock and energy minerals without significant impacts using modern technology, today we have to recognize that there will likely be a question of simply whether we should mine in a given place, or mine a particular commodity. This can be motivated for a variety of reasons such as climate change, but also to address local labor and health and safety as well as economic interests, protected places, drinking water aquifers, the interests of sovereign nations and other places deemed unique, or situations where it is desired for whatever reasons might exist globally or be present locally to consider the appropriateness of mining. It's a complex undertaking, but in order to meet the expectations of innovative technologies and accomplish our goals for safety and environmental control, we must look upon the address of larger societal issues as a key part of the challenge, and not forget they must be part of the undertaking, or we risk having yet not learned the wisdom of Agricola.

Chairman Lamborn, members of the Subcommittee. Thank you again for inviting me to testify on the important subject of modern mining safety, environmental controls, and technological innovation.