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Industry Study

Final Report

Strategic Materials

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Foreword

When the Eisenhower School for National Security and Resource Strategy Class of 2020 started the school year, each of the approximately 300 students felt a rush of excitement peppered with uncertainty. A majority of the incoming class had been away from traditional academia for several years, even decades. As students embraced academia and started to flourish, the excitement returned as the second semester included the coveted industry travel, which was the allure that brought many of the students to Eisenhower. But, like the start of the school, uncertainty returned in the form COVID-19. At first, COVID-19 was a far-reaching idea that was only affecting China, but very quickly as the virus spread, the reality set in that the virus was going to have huge impacts on the world and the way we learn. Each day the uncertainty grew, as did the precautions added by Eisenhower to protect students and their families. At the same time, we watched our coursework on mobilization unfold in front of us on a national level in real-time.

The academic theories on mobilization quickly became a reality, and the students of the Eisenhower school quickly understood the value of the education they were receiving. On a personal level, the impacts of the virus were immediate. First, came the cancellation of core travel. Second, was the move to a virtual platform for learning meant we lost connection with our faculty and classmates and industry. With excellent credit to the faculty, they quickly adapted to enhance our learning in this challenging environment. Our connections and efforts ensured that we still were able to interact with our industry partners in the virtual world. While we achieved the learning objectives, the shift to virtual learning simply cannot replace real-world learning, especially in the strategic materials landscape.

In many cases, we do not readily see strategic materials, and their applications are rarely understood. The virtual environment could not replicate the first-hand knowledge of seeing the processing and extraction in a mine. The most significant loss was the interactions with experts in the field, not only the senior leaders but the workers and middle management that are key to the success. The hope is that next year's class will be able to benefit from the industry travel, which makes the Eisenhower education unique. Rest assured, the education that students receive from the Eisenhower School, regardless of how the platform will pay dividends. Each graduate of the Eisenhower School, armed with their knowledge, will influence change and excel as civil leaders by applying the founding virtues and standards of the Eisenhower School.

Strategic Materials (STRATMAT) 2020

ABSTRACT: *Strategic materials are found everywhere in modern society – in smartphones and consumer electronics; in guidance systems for precision munitions and other weapon systems; and in windmills and solar panels that provide alternative energy sources. 21st century life as we know it would not exist without critical minerals such as rare earth elements. The United States dominated world production for many of these materials until the 1990s. Following the end of the Cold War and decades of increased economic globalization, the U.S. now finds itself reliant on foreign sources for these important minerals, primarily from the People's Republic of China. This report focuses on the national security importance of strategic materials, identifies vulnerabilities inherent in the current global supply chain, and makes policy recommendations to strengthen national security.*

NOTE: *The COVID-19 pandemic of 2020 directly impacted Eisenhower School operations by curtailing planned industry travel and forcing a transition to online instruction starting in mid-March 2020. The virus response exposed the many risks of global supply chains and over-reliance on any one country for critical materials and products. Eisenhower School students watched academic theories on mobilization quickly become reality as tools like the Defense Production Act became part of the daily national news cycle. As the world continues to rapidly change as a result of COVID-19, the mining and processing industries that provide strategic materials will certainly be impacted in both predictable and unforeseen ways.*

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Industry Study Outreach and Field Studies

The STRATMAT team would like to extend a heartfelt thanks to all of the industry, government, academic and international leaders in this area who took time out of their busy schedules to educate, inform and promote creative thought within our team.

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Table of Contents

Introduction
- **Purpose**
- **Summary of Findings**

Strategic Materials and Implications for National Security

U.S. Industrial Policy
- **History of Business-Government Relations in Strategic Materials**
- **Social, Environmental, and Ethical Issues in Strategic Materials**
- **Legal Hurdles to the U.S. Mining Industry**
- **Acquisition and Mobilization (National Defense Stockpile & Defense Production Act (DPA))**

Structure, Conduct, and Performance of the U.S. Mining Industry
- **Porter's Five Forces Analysis**
- **Firm Behavior in the U.S. Mining Industry**
- **Financial Performance in the U.S. Mining Industry**

Current Business Risks and Trends in U.S. Mining and Metals (SWOT Analysis)
- **Innovation as a Strength**
- **Workforce as a Weakness**
- **Green Economy Demand as an Opportunity**
- **License to Operate as a Threat**

Industrial Mining Policy Shaping the Great Power Competition
- **Chinese Industrial Policy in Strategic Materials**
- **Russian Industrial Policy in Strategic Materials**

Policy Recommendations

Conclusion

Appendices

I Acronym List

II Supply Chain Risks Essay

III Chart - 2019 U.S. Net Import Reliance on Critical Minerals

IV Figure 3 – Current Status of DLA Stockpiles

V Figure 4 – DLA Stockpiled Commodities Over Time

VI Essay – Innovation in Strategic Materials
- **U.S. National Innovation System in Strategic Materials**
- **Sources of Innovation in Strategic Materials**
- **Information Technology & the Future of Mining**

VII Essay – Human Capital as a Source of Competitive Advantage

VIII Strategic Materials Firm Briefs

Introduction

Purpose

The mission of the Eisenhower School for National Security and Resource Strategy is to inform senior leaders from across the military and civilian agencies how to effectively evaluate, marshal, and manage resources in order to execute national security strategy.[1] A key component of the curriculum includes Industry Studies, wherein students explore key segments of the U.S. and global industrial base in order to discover how those segments impact national security resource requirements. The Strategic Materials Industry Study seminar focuses exclusively on critical non-fuel minerals and their importance to defense and non-defense industries.[2] During the Academic Year 2020, the team examined how these critical minerals are explored, extracted, refined, and incorporated into an ever-increasing array of high-tech products, including sustainable energy, commercial and defense applications. Moreover, the seminar investigated the supply chain for critical minerals and compared the various policies governments around the world employ to ensure current and future access to scarce resources. During the course of its research, the Strategic Materials Industry Study collaborated with various stakeholders from government, industry, and academia in the National Capital Region, Ohio, Colorado, and California; in doing so the seminar gained a comprehensive understanding of the opportunities and challenges associated with growing and maintaining a healthy industrial base for strategic materials in order to provide for the nation's economic prosperity and national security.

Summary of Findings

The use of minerals has always defined societies. From the Bronze Age to what some scientists are calling the "Rare Metal Age" of the early 2000s, minerals play a key role in the technologies people use to live, work and play.[3] Today, the new and innovative uses for minerals are pushing the boundaries of technology in ways that couldn't have been imagined 20 years ago. In fact, "at no point in human history have we used more elements, in more combinations, and in increasingly refined amounts."[4] However, the increasing demand for minerals has magnified the issues surrounding domestic and international supply, as well as shone a spotlight on how strategic and critical materials can impact a country's national and economic security.

Critical materials are those nonfuel minerals that are essential to the economy, while strategic minerals are those used in defense applications. Both are characterized by supply chains that may be vulnerable to disruption and the absence of which could have grave consequences for national security or the economy. Although the United States (U.S.) is undeniably blessed with an abundance of natural mineral wealth, the last three decades have seen the U.S. go from a world leader in extraction and exports of strategic minerals to the world's greatest importer. In response to the threat this poses to U.S. supply chains that rely on strategic minerals, Executive Order 13817, titled *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*, was released in 2017. It established policy goals of identifying new sources of material, increasing production across the entire supply chain, improving industry access to mapping data, and streamlining the permitting process. The Department of Commerce followed suit in 2019 with its comprehensive call to action plan to secure the supply of critical minerals as well as increase the resiliency of the supply chain both at home and abroad.

Yet more work remains in order to stimulate a vibrant commercial domestic mining industry in the U.S. The U.S. faces complicated challenges stemming from (a) the high costs associated with the capital intensive nature of the industry, (b) industrial practices in other

countries that often make it cheaper to extract or process minerals abroad than in the U.S., (c) labor shortages in key STEM fields needed to produce innovation breakthroughs in processing and smelting methodologies, (d) permitting processes that can take years to resolve, and (e) a long history with companies shirking environmental and social responsibilities. Furthermore, the industrial policies of China and Russia with respect to strategic minerals often exacerbate the tension inherent in great power competition.

Therefore, this paper lays out a series of recommendations designed to correct several market failures and further stimulate the domestic mining industry. In order to increase participation by new firms, the Seminar recommends modernizing the rental permitting payment structure, allowing the pooling of reclamation bonds, entering into long-term contracts with U.S. companies to provide critical minerals for the National Strategic Stockpile, and enacting legislation that approves federal mining permits if a decision is not provided by the responsible agency within 180 days. In order to address market inefficiencies due to externalities, the Seminar recommends taxing certain imports of strategic minerals and collecting federal mining royalties that could be used to offset federal responsibilities such as cleaning up abandoned mines. Finally, since private markets underinvest in actions with public good outcomes, the Seminar recommends re-instituting the Bureau of Mines (to prioritize and coordinate mining research and innovation activities), adding the Department of the Interior to the board of CFIUS, requiring mandatory geological reporting as a condition of mining Plan of Operation acceptance, funding mining-related STEM scholarships, promoting public awareness of the importance of minerals in low-carbon energy sources, and finally establish the Rare Earth Minerals Initiative with other like-minded nations in order to demand transparency, rule of law, anti-corruption measures, open markets, and respect for labor and environmental standards.

Strategic Materials and Implications for National Security

Materials alone do not equate to power. Power arises from the possibility of turning materials into technologies and, ultimately, capabilities. These especially important materials are strategic or critical materials. Strategic Materials include minerals, metals, and byproducts, which are domestically and globally traded commodities. Prior to 2018 and because a material's value is in the eye of the beholder, organizations with the U.S. Government (USG) had individual lists of minerals critical to each agency's mission. Furthermore, the priorities of critical materials shift periodically depending on technology, research and development (R&D), and available reserves. Executive Order 13817 defines critical materials as those nonfuel minerals that are essential to the economy, while strategic minerals are those used in defense applications.[5] Both are characterized by supply chains that may be vulnerable to disruption and the absence of which could have grave consequences for national security or the economy.

Americans born in 2013 "will consume three million pounds of minerals, metals, and fuels over [their] lifetimes."[6] Iron ore makes steel for planes, trains, automobiles, and buildings.[7] Copper is used in electronic parts, electricity infrastructure, and plumbing.[8] Rare earth elements (REE) are critical for cell phones, flat-screen televisions, batteries for electric vehicles, and magnets for wind turbines.[9] Domestic mining is, indeed, critical to the U.S. economy. In 2019, domestic mining produced about $86.3 billion in raw materials.[10] These raw materials were then consumed by several downstream industries (e.g., defense and construction), which added about $3.13 trillion in value to U.S. gross domestic product (GDP) in 2019 ($21.43 trillion).[11]

As a result, the defense sector competes with the commercial sector for the same critical minerals. The importance of these two vectors stimulates the U.S. to secure a secure supply of critical minerals. (See Appendix II for supply chain risk essay.) Although the country is rich with mineral resources, it is reliant on the import of many of the critical minerals from countries such as China, Chile, Australia, and the Democratic Republic of the Congo. (See Appendix III for U.S. import reliance chart.) The goal is to reduce if not eliminate the vulnerability to disruption of the critical minerals' supply chain: "[O]ur nation's mission [is] to reduce our vulnerability to disruptions in the supply of critical minerals. Any shortage of these resources constitutes a strategic vulnerability for the security and prosperity of the United States"[12]

Moreover, in the area of critical minerals, the United States, China and much of the rest of the world are today – to paraphrase Joseph Nye and Robert Keohane – stuck in an international relationship defined by interdependence.[13] The sum total of our international transactions – the flow of goods, resources, money, and so on – is such that we are beyond interconnected, a situation where we engage in the exchange but are free to act independently without significant cost,[14] but instead we are interdependent because the exchange leaves us in a situation of mutual dependence. Neither side can act independently. We depend on China to process rare earths and other strategic materials. China depends on us for markets in which to sell Chinese-made goods, access to capital, and technology.

The U.S. is cooperating with two allies to mitigate the strategic vulnerability of its critical mineral supply chain. First, the U.S. and Canada launched the U.S. - Canada Critical Minerals Action Plan in January 2020, dedicated to "securing the supply of critical minerals for strategic industries and defense; improving information sharing on critical mineral resources; engaging with the private sector; and working together in multilateral fora and with third countries."[15] Defense funding for critical minerals projects, and strategic investments in North American processing facilities, were reported to be key parts of the joint plan.

The U.S. and Australia are working closely together to create a critical minerals supply chain independent of China. Australian mining company Lynas – the largest rare earths company outside China – is partnering with an American company to build a new rare earth processing plant in Texas that they hope will receive funding from the Pentagon. At the governmental level, the United States and Australia have launched the U.S.-Australia Critical Minerals Action Plan to improve the security and supply of rare earths and other critical minerals.

U.S. Industrial Policy

History of Business-Government Relations in Strategic Materials

According to the Congressional Research Service, the goal of U.S. policy towards strategic materials is "to promote an adequate, stable, and reliable supply of materials for U.S. national security, economic well-being, and industrial production."[16] This current policy has gradually coalesced since the 1872 National Mining Law through a series of incentives to promote domestic production, regulations to manage the industry, a national stockpile to protect the defense industrial base, and more recently, steps to protect the foreign supply of materials.[17]

A key component of the 1872 law that incentivized mining was, and continues to be, indirect subsidies. A claim owner on federal land may extract minerals without paying rent or royalties to the government, making the land use and title to the minerals essentially free. If a miner seeks to establish exclusive title to a claim through a process called patenting, it only costs between $2.50 and $5.00 per acre. This is another indirect subsidy as the claimant is paying far less than the market value for the mineral rights. A third subsidy takes the form of tax incentives including the depletion allowance of mineral resources. Another important incentive is the ability to write off the costs associated with exploration and development.[18]

In addition to subsidies, an agency came into being in 1910 that would impact strategic materials policy for most of the 20th century. In 1907, a spike of over three thousand coal mining fatalities caught the attention of the populace and led the Sixty-first Congress to establish the Bureau of Mines (USBM) three years later. Its original commission was to improve mine safety, test coal for the government, and reduce fatalities. This was expanded in 1913 to include economic development of the mining industry, conservation, and the study of mineral processing. The USBM quickly became respected as the world leader in mineral information. Its early research led to multiple innovations including low-cost radium for healthcare. The bureau also developed gas masks, explosives, and critical mineral extraction technology that proved essential for World War I.[19] While the new agency gained its footing, strategic materials policy began an irreversible march towards national defense.

The 1939 Strategic and Critical Materials Stock Piling Act directed the USBM to conduct research on, "mining, preparation, treatment, and utilization of ores essential to national defense and industrial needs."[20] Geologists and engineers from the bureau evaluated hundreds of potential ore deposits for the war effort and discovered numerous low-grade reserves. The agency's metallurgists then tackled the challenge of extracting the minerals locked in the lower-grade ore. Finding and assessing mineral resources on public lands remained an important mission of the USBM for the remainder of its existence.[21]

As the country embraced the challenges of World War II, the War Production Board (WPB) assisted domestic industries in getting their most important strategic materials needs met. This involved the systematic prioritization and allocation of scarce resources. It is important to note that this effort did not devolve into a command economy like the Soviet Union. Instead, the WPB

and the Roosevelt administration developed a distinctive economic framework whereby the government injected significant regulation, oversight, support and funding. However, control of individual industries was left mostly to private businesses that fully leveraged free market incentives and the immense flow of government spending.[22]

Worldwide sourcing was a key wartime policy in acquiring commodities not available domestically. Out of the three major materials deemed strategic during the war, steel and aluminum were sourced and produced primarily with U.S. ore and production facilities. Copper presented a much different problem. The U.S. produced less than two percent of the copper needed for war production, even after significant financing to expand existing mines and open new mines that eventually totaled 270 in operation. To curb demand, the WPB substituted silver in many applications, which was more expensive but readily available.[23] Most of the copper shortfall was made up by foreign sources, most significantly Chile, Mexico, Peru and the Belgian Congo. Chile diverted much of its copper sales from Europe during the war, with exports to the U.S. more than tripling. Similarly, the Belgian Congo shifted most of its copper exports to the U.S. after European markets were cut off.[24]

After the war, Congress continued USBM funding to further develop mineral extraction technology from low-grade ore. The bureau had multiple production plants and demonstration projects operating by 1950. Its research center in Albany developed a process named after Dr. William Kroll to refine hafnium, zirconium and titanium. The facility also refined the zirconium used in the first U.S. nuclear submarine, and its production technology helped create the U.S. industry for the same metal as well as titanium.[25]

The midpoint of the century also saw the start of the Mountain Pass Mine in California after a nearby discovery of bastnaesite ore. Demand for rare earth elements (REEs) was increasing and bastnaesite was found to contain them in relatively high concentrations. The mine began producing in 1954 and was the world's leading extractor of REEs between 1965 and 1995.[26] According to geographer Julie Klinger of Boston University, the discovery and production of the mine was so impactful, "that a period of relative calm and stability settled around the production of rare earths."[27]

Two decades later, a government agency was created that would have long-lasting impacts on the mineral industry and the Mountain Pass Mine. The Environmental Protection Agency was established by President Nixon in 1970 to codify and enforce a labyrinth of state and local environmental laws.[28] The agency's purview gradually expanded to include not only air and water but many activities associated with the extraction and processing of minerals.[29] Within three years of the Environmental Protection Agency's (EPA's) founding, Lindsay Chemical Company, the oldest processor of rare earth minerals in the United States, closed down due to the economic impact of complying with the new pollution standards. Five years later, the world's largest ion-exchange plant producing rare earth minerals owned by the Michigan Chemical Corporation closed for similar reasons.[30]

By the 1990s, the U.S. peaked as the world's leader in extracting and exporting strategic minerals. A sharp decline followed to the point where America became the world's greatest importer. In addition to cheap imports becoming available from China, three government policies were often cited as contributing to this shift. First, access to significant portions of state and federal lands for mining had been withdrawn. This put numerous proven ore reserves out of reach for development. Another factor was the gradual creation of highly bureaucratic and cumbersome permitting requirements. New mines typically took between seven and ten years to obtain permits

necessary for startup. A third policy driver was significant environmental regulation and litigation that killed many mining ventures.[31]

Ironically, the USBM was shuttered about this same time by the Clinton administration and a Congress looking for budget cuts. The bureau represented only two percent of the Department of the Interior's budget and had been cited as having stellar financial management and efficiency. While its future was being debated in Congress, the American Institute of Mining, Metallurgical and Petroleum Engineers sounded a prophetic warning:

> This factor [the value of USBM objective research] will become an increasingly important federal asset in the years ahead as the nation intensifies its struggles to cope with the massive problems related to the growing, worldwide demand for mineral resources. To throw such an asset away solely for the sake of budget cutting would be penny wise and pound foolish in the extreme.[32]

Nonetheless, the bureau that had won 35 awards for R&D during its 86-year life was closed in 1996. Several of its functions were transferred to other agencies. Most of its laboratories and demonstration projects were shelved.[33] The budget savings to taxpayers was a paltry $132 million[34] out of a $1.56 *trillion* federal budget.

Extraction and processing of rare earth minerals rapidly declined in the United States from the mid-1990s until 2002. By the start of the new century, almost all rare earth oxides were being imported from China due to cheaper production costs. The Mountain Pass Mine in California suffered a spill of contaminated processing water in 2002. Due to this and mounting environmental and regulatory challenges, the mine ceased operations. Much of the nation's expertise and capacity in the strategic materials supply chain were lost as rare-earth production shifted almost exclusively to China.[35]

The United States and much of the world appeared content with this new status quo until a dispute arose in the East China Sea. In September of 2010, a Chinese trawler intentionally rammed two Japanese Coast Guard vessels. The boat had been fishing illegally near the Japanese-controlled Senkaku Islands. In response to the ramming, the Japanese promptly arrested the 15-man crew and captain. The Chinese retaliated with several measures including an embargo of REE exports to Japan. Ninety percent of Japan's REE supply came from China, and the standoff threatened to severely disrupt its economy. Japan chose to back down and released the crew to de-escalate the situation. The incident gained international attention and demonstrated China's ability to use its near monopoly of rare earth elements as a coercive instrument.[36]

China's 2010 actions sent shockwaves through rare earth markets and the halls of Congress. As prices of critical minerals soared, lawmakers debated and introduced a variety of bills. These included attempts to streamline the federal permitting process for mines, adding specific minerals to the national stockpile, and commissioning studies to determine the extent of the danger.[37] In 2017, the Trump administration refocused these efforts with Executive Order 13817, titled *A Federal Strategy To Ensure Secure and Reliable Supplies of Critical Minerals*. The resulting document outlined an approach to reduce the United States' vulnerability to disruption within critical mineral supply chains. It also established a policy aimed at identifying new sources of material, increasing production across the entire supply chain, improving industry access to mapping data, and streamlining the permitting process. The order commissioned two important reports from the Secretaries of Interior and Commerce. Developing a list of critical

minerals was assigned to the former while the latter was tasked with developing an overarching strategy.[38]

Answering the administration's directive, the Department of the Interior in 2018 designated as "critical" thirty-five minerals with significant analysis by its subordinate science agency, the U.S. Geological Survey.[39] The Department of Commerce followed suit in 2019 with its strategy report. The comprehensive plan included six specific calls to action including transformational research and development coupled with strengthening the entire mineral supply chain. Increased cooperation and trade with allies highlighted the perceived risk from Chinese imports. Other calls to action were improved mineral mapping of the United States, streamlining mining permits, and increased access to federal lands.

Social, Environmental, and Ethical Issues in Strategic Materials

"The Congress, recognizing the profound impact of man's activity…declares that it is the continuing policy of the Federal Government…to create and maintain conditions under which man and nature can exist in productive harmony…."[40] Though these opening words of the National Environmental Policy Act (NEPA) brought hope to Americans enduring toxic communities 50 years ago, NEPA and its progeny are now often blamed for unnecessarily increased input costs for the U.S. mining industry[41] as well as the Nation's subsequent reliance on imports for minerals critical to the economy and national security.[42] However, foundational tenets of America's democracy – not environmental regulations themselves – are the real cause.

Mining led to the steel industry, glass manufacturing, and triumph in World Wars I and II.[43] Mining also devastated the environment and exploited social inequalities. This negative history overshadows many of the benefits from mining and is the likely fuel for anti-mining and preservationist sentiments in the U.S. Although research and data often distinguish coal from metal/non-metal mines, the American public probably does not appreciate the difference. To most Americans, a mine is a mine.

Social and Environmental Issues: In the early 1900s, mines were located in remote areas with poor conditions, and miners were immigrants, children, and the disadvantaged, who suffered disease and death as a result of their employ.[44] Even after more than a century, many of today's images harken back to the adverse impacts on these impoverished miners. Conditions have since improved, and the number of fatalities in the entire mining industry steadily decreased from over 3,000 in 1900 to about 200 in 1980.[45] In the last five years, there have been less than 30 annually.[46] However, miners continue to be plagued by respiratory diseases. From about 2005 to 2015, dust-induced lung disease and respiratory hazards increased across the mining industry.[47] Finally, in the upper Midwest, mining negatively impacted Native American Tribes. Beginning in the 1960s, tribal members have asserted treaty rights in opposition to mining development, which threatened the tribes' way of life and ancient places of worship.[48]

With regard to the environment, gold was previously extracted with mercury – one of the most environmentally hazardous metals – which was subsequently dumped into the nearby soil or water.[49] Despite technological advancements and environmental regulations, today's mines still produce significant waste. Milling and smelting processes to extract minerals from ore use hazardous chemicals such as cyanide,[50] and some smelting processes produce sulphur dioxide, which will create acid rain if it reacts with water vapor.[51] Additionally, once the minerals are removed from the ore, the remaining ground rock (tailings) may contain dangerous byproducts such as arsenic.[52] Some of the most environmentally damaging minerals are also the key to renewable energy sources – rare earth elements (REE).[53] For example, producing one ton of REE

in China results in "more than four tons of sulfuric acid and one ton of hydrochloric acid and sodium hydroxide."[54] This is all in addition to the 22,500 abandoned mine features throughout the U.S., which are environmental hazards.[55]

Ethics Issues: What is the USG willing to do to attain mineral independence and fulfill the National Security Strategy's mandate to "put the safety, interests, and well-being of our citizens first?"[56] Although several may be identified, two ethical issues are of particular interest: (1) Is it acceptable for industries to damage the environments of foreign countries to provide cheap goods to Americans; and (2) to what extent should America's own land and citizens be exploited to gain mineral independence? The first question highlights what many view as America's greed and hypocrisy. It is difficult for the U.S. to tout freedom, peace, and democracy while also purchasing cheap goods (e.g., cell phones) that are produced by dumping radioactive residues into lakes that then create "cancer villages."[57] The second question, in turn, highlights the American dilemma of preserving nature and protecting it from human interference versus being good stewards and finding responsible uses of the resources.[58] Neither has easy solutions and is only further complicated by today's political divide. As of 2017, the American public is evenly split on whether reduced environmental regulations can still protect the quality of America's environment,[59] and public opinion on environmental issues is more partisan than 10 years ago.[60]

Legal Hurdles to the U.S. Mining Industry

The mining industry and outside critics often blame the U.S. permitting system for the disincentive to develop mines and for lost investment opportunities.[61] According to National Mining Association research, firms complete the necessary permits for a large mine in the U.S. in seven to ten years on average versus only two years in Canada and Australia.[62] Indeed, Western Australia topped the 2020 annual review of the world's most attractive jurisdictions for mining investment with South Australia ranking 6th out of 76 worldwide jurisdictions considered.[63] Nevada, Alaska, Idaho, and Arizona ranked 3rd, 4th, 8th, and 9th respectively.[64] Though a strong performer in the past, no Canadian province was in this year's top 10 due to concerns with environmental regulations as well as land and title claims.[65]

Permitting is only one specific legal hurdle impacting the U.S. mining industry, however. From a broader perspective, the various legal challenges facing this industry in the United States stem from three sources: (1) America's history of federalism, (2) the Executive Branch and its relationship to the Legislative Branch, and (3) the role of the Judiciary.

History of Federalism: Federalism is "[t]he relationship and distribution of power between the national and regional governments within a federal system of government."[66] In the U.S., this division of power exists between the Federal Government and the fifty states. That is, firms must comply with Federal *and* State laws and agencies (see Figure 1[67]), which may not coordinate with each

FIGURE 1

Categories of State and Local Permits and Authorizations That Mine Operators May Need to Obtain To Conduct Mining Operations in 12 Western States

State	Air quality	Hazardous materials and waste[a]	Mining	Operations[b]	Safety[c]	Water quality[d]	Other environmental[e]
Alaska	•	•	•	•	•	•	•
Arizona		•	•	•	•	•	•
California	•	•	•	•	•	•	•
Colorado	•		•	•	•	•	
Idaho			•	•	•	•	
Montana		•	•	•	•	•	•
Nevada	•	•	•	•	•	•	•
New Mexico		•	•	•	•	•	•
Oregon			•	•	•	•	•
Utah	•		•	•	•	•	•
Washington	•	•	•	•	•	•	•
Wyoming	•		•	•	•	•	

Sources: GAO analysis of selected National Environmental Policy Act documents, state permitting guides, and studies of hardrock mining requirements. | GAO-16-165

other and may implement duplicative requirements. One example is NEPA and its state equivalent - SEPA (State Environmental Protection Act). The challenges are further complicated because states may enact different statutes (e.g., different versions of SEPA).

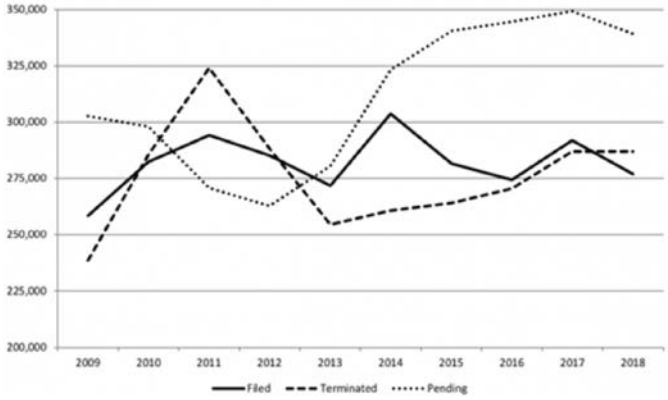
The U.S. Constitution allows the Federal Government to preempt states.[68] As a result, the Federal Government could remove any duplication from state statutes and wholly regulate mining.[69] However, the Congress chose (and continues to choose) to pass Federal laws while also preserving each State's authority to pass laws to preserve its citizens' health and security. This is in contrast to Australia, where the states are responsible for environmental regulation of mining.[70] This division of labor and avoidance of conflicts between the Federal (i.e., Commonwealth) and State Governments is codified in the *1992 Intergovernmental Agreement on the Environment* whereby the Commonwealth only intervenes on environmental matters of international and national concern.[71]

The Executive Branch and its Relationship to the U.S. Congress: In the U.S., the Executive and Legislative Branches are two of three distinct branches of Government. Separate elections determine the President of the United States (POTUS) and the members of the Congress. Australia, on the other hand, has a parliamentary system of government consisting of two houses in the Parliament and a federal executive. Members of the federal executive, including the head of the Executive Branch (i.e., Prime Minister), are selected from members of Parliament.[72] Consequently, Australia does not experience the gridlock and partisan gaps often experienced between the Legislative and Executive Branches in the U.S.

Additionally, the bureaucracy of the U.S. Executive Branch further exacerbates the complexity of legal requirements created by the Federal Government and the fifty states. In addition to the EPA, several other agencies review mining operations and may be the lead agency for those issues.[73] These agencies also compete with each other for resources (e.g., manpower and funding), and with the likely increase in mandatory expenditures,[74] an even smaller amount of discretionary spending will be available to these Executive agencies in the future. As a result, the processing of statutory and regulatory requirements may slow down even more.

The Role of the Judiciary: The third distinct branch of the USG is the judiciary, which "interpret[s] the law, determine[s] the constitutionality of the law, and [applies] it to individual cases."[75] In addition to appeal processes through specific Executive agencies, citizens may seek judicial review of agency decisions. It is critical to note the significant number of cases managed by today's courts[76] (see Figure 2[77]). Pending litigation may delay mining development until its resolution, may result in the revocation of issued permits, and may add the cost of attorneys' fees to a firm's already high capital costs. Once a mine begins commercial development, its exposure to litigation does not vanish. Firms must continue to comply with regulations or face even more litigation (e.g., toxic tort litigation for wrongfully exposing citizens to toxic substances[78]). Moreover, there is some discussion on expanding the types of cases presented in U.S. courts by allowing individuals with injuries based on climate change rather than

FIGURE 2
Civil Cases Filed, Terminated, and Pending
12-Month Periods Ending March 31



the current, more restrictive, requirement to demonstrate "an actual or imminent injury."[79] The legal challenges to the U.S. mining industry are more complex than any single set of statutes or administrative regulations.

In sum, today's environmental regulations are, in fact, a reflection and product of America's democratic processes, but they may also be jeopardizing economic growth and national security. America cannot allow its greatest strength – democracy – to also be the source of its downfall.

Acquisition and Mobilization (National Defense Stockpile & Defense Production Act (DPA))

Strategic and Critical Materials Stock Piling Act: In 1939, Congress passed the "Strategic and Critical Materials Stock Piling Act (50 U.S.C 98),"[80] as a hedging strategy to secure adequate raw materials required for the production or replenishment of defense equipment. "The current goal of U.S. mineral policy is to promote an adequate, stable, and reliable supply of materials for U.S. national security, economic well-being, and industrial production."[81] According to the Strategic and Critical Materials Stock Piling Act (as amended through P.L. 116–92, enacted December 20, 2019], Congress determined that some critical materials were deficient in supplying military requirements. The purpose of the Act was to acquire and retain critical materials important to the national defense of the U.S. Additionally, the Act also determined the importance of not depending upon foreign resources for critical materials necessary for national defense.[82] This Act underscores Congress's awareness of the issue and the importance of taking action to help address this vulnerability.

Importance of Stockpiles of Strategic Materials: Military affairs author and former Marine Corps officer Carlton Meyer notes that:

> Establishing a strategic materials program seems dull and wasteful during peacetime, yet pure genius during wartime. It will buy time for leaders to find alternatives to whatever materials are unavailable or take diplomatic or military steps to secure vital materials. Having a stockpile may even dissuade a hostile nation from attempting a blockade or embargo. In addition, stockpiles can be drawn upon during supply disruptions caused by weather, natural disasters, union strikes, or wars elsewhere.[83]

Limited supplies of strategic materials in the National Defense Stockpile (NDS) indicate a dangerous reliance on countries that cannot be trusted, however. (See Figure 3[84] in Appendix IV.)

COVID-19 perfectly illustrates the importance of having a stockpile yet still being reliant on the outsourcing of materials critical to the nation's wellbeing. Given shortages of ventilators and outsourcing of pharmaceuticals to China, the U.S. finds itself in a desperate situation as it tries to mobilize the health care industry. The National stockpile became one of the first options for the provision of the equipment and medicine necessary to treat the thousands of patients stricken by the virus. Thus, stockpiles represent a significant and important component of our national defense and economic stability.

Stockpiles help to protect against vulnerabilities in supply chains; however, they can only last for a period of time. Eventually the stockpile may run short of strategic materials. In fact, the National Resource Council (NRC) observed that, "[T]here have been significant lags at a number of points: between changes in military planning and the scenarios used for modeling stockpile requirements, between stockpile requirements and legislated stockpiles goals, and between goals and NDS inventory levels."[85] The actual amount of minerals held in the stockpile has decreased

significantly over the past few decades (see Figure 4[86] in Appendix V); this inevitably puts the economic and national security at risk if we were to experience a national shortage, similar to the personal protective equipment shortage that arose during the COVID-19 pandemic.

Defense Production Act (DPA) and Strategic Materials

The DPA[87] authorities provide the federal government flexibility in crisis response and prioritize resources to provide for our national security and defense. The federal government also uses the DPA authorities to assess and mitigate risks to the economy, access materials deemed "critical" or "strategic," and protects the health of the defense industrial base against realties of a "free-market economy." One noteworthy point, however, is that the DPA is not permanent legislation, as Congress must reauthorize the DPA legislation periodically. The current DPA enacted in 2018 will expire on September 30, 2025.

The DLA Strategic Materials group manages the acquisition and disposal of materials in the National Defense Stockpile.[88] The most significant authorities that could help protect the supply chains of strategic materials are in DPA Title III – "Expansion of Productive Capacity and Supply."[89] Title III has multiple tools for the President to use to protect the national defense and industrial base.[90] Program Managers use the authorities to conduct market research, support R&D initiatives, and draft policies to protect the industrial base.

The DPA Programs use the public-private partnership to promote expansion in critical industries and, ultimately, transfer ownership of capital to the partner firm. Specifically, the Title III Program authorities include: (1) purchasing or making purchase commitments of industrial resources or critical technology items; (2) making subsidy payments for domestically produced materials; and (3) installing and purchasing equipment for government and privately owned industrial facilities to expand their productive capacity.[91] The DoD, under the Defense Production Act of 1950, also has a list of minerals, metals, and materials deemed "strategic" and "critical" for national defense. The priorities of critical materials shift periodically depending on technology, R&D, and available reserves.

The U.S. Geological Survey (USGS) published the Mineral Commodity Summaries 2020 report, which identified minerals facing supply risks due to high reliance on imports from China, Russia, and other fragile nations.[92] That said, the multiple tiered supply chains for strategic materials makes it harder to quantify actual dependence on foreign materials. The DLA Strategic Materials group works with subject matter experts from the USGS and other partners to monitor the commodities markets for signs of disruption to the supply. For example, the group collaborates with the OSD Manufacturing Technology (ManTech) and Industrial Base Analysis and Sustainment (IBAS) "to address national security risk within market activities."[93] Furthermore, in 2019, Congress directed the Government Accountability Office (GAO) to study the "Defense Supplier Base Challenges and Policy Considerations Regarding Offshoring and Foreign Investment Risks."[94] Dr. Christine Michienzi,[95] the Director of Industrial Assessment, described how the DPA Title III Program and DLA Strategic Materials group rely on data compiled by the IBAS team on mergers and acquisitions "to address national security risk within market activities."[96] The lack of a centralized management system across the federal government introduces the risk of data accuracy.

The DoD uses the authorities of the DPA Title III to secure materials such as rare earth elements (REEs). The specific REEs sought by DLA Strategic Materials in 2020 include:

(1) Light Rare Earth Elements

(2) Heavy Rare Earth Elements

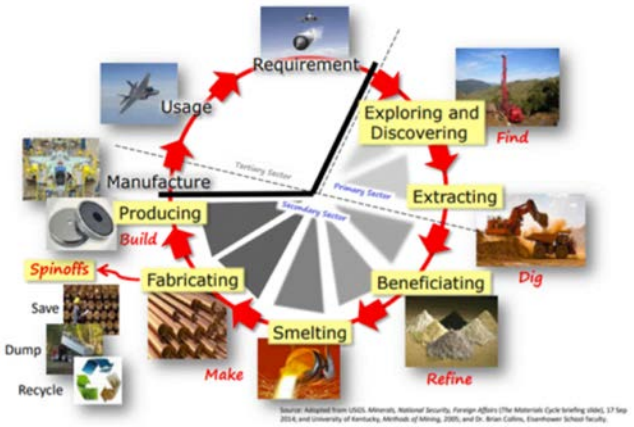
(3) Rare Earth Metals and Alloys
(4) Neodymium Iron Boron Rare Earth Sintered Material and Permanent Magnets, and
(5) Samarium Cobalt Rare Earth Permanent Magnets.

In the case of REE, China's dominance in processing and production increases supply risks given its control of the quantity available for export. China also can withhold or "dump" supply to influence market prices. Members of the Defense Production Act Committee (DPAC),[97] along with those of the Bureau of Industrial and Security National Defense Stockpile Market Impact Committee (MIC), understand how such variables increase supply chain risks. The Air Force Research Laboratory (AFRL) is conducting market research for "Light and/or Heavy Rare Earth Element Separation and Processing Production Capability."[98] The MIC and AFRL are two key entities conducting research into the forces affecting the mining industry. A detailed analysis of these impacts using Porter's Five Forces is useful in understanding the industry dynamics.

Structure, Conduct, and Performance of the U.S. Mining Industry

A Five Forces analysis reveals key characteristics of the mining industry. Most notable are high upfront capital costs, high exit costs, and high fixed costs relative to marginal costs. It is expensive to acquire mining and water rights, purchase equipment, and obtain permitting. Upfront costs also include large bonds to cover potential environmental impacts. Exits costs are high due to minimally transferable assets and substantial site remediation actions. As a result, it takes mining companies years of operations before turning a profit, and you cannot simply walk away from a poorly performing mine. (See Figure 5.)

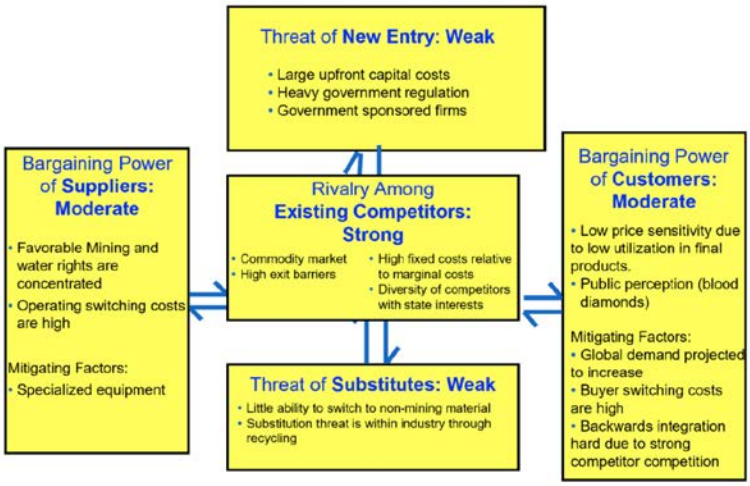
FIGURE 5
STRATEGIC MATERIALS INDUSTRY CYCLE



Porter's Five Forces

The government needs to understand the structure and influences impacting the mining and metals industry in order to better support future domestic production. Understanding the competitive nature and how or what makes a certain industry profitable will ensure the right policies are put into place. To understand the structure, economics, and outcomes prevalent in the mining and metals industry, a framework is needed to capture a complex environment containing countless variables.

FIGURE 6
Porter's Five Forces Analysis of U.S. Mining Industry



Michael Porter's Five Forces of competition framework, first described in an article titled "How Competitive Forces Shape Strategy" and published in the Harvard Business Review in March of 1979, identifies five major forces to account for the numerous variables present within the state of competition for a given industry (see Figure 6).

Power of Buyers: Moderate

The bargaining power of buyers comes down to two things: price sensitivity of the buyer and leverage to negotiate a lower price. The vast usefulness of critical minerals and the necessity of the products in which they are used reduces price sensitivity. This is typically further reduced because the overall cost of critical minerals needed in a product is often a small proportion of the total cost of production. However, the inability for the mining and metals industry to generate product differentiation results in low switching costs and increases price sensitivity and buyers' power when negotiating.

Many buyers of critical minerals are large companies or governments with considerable financial backing which allows them to negotiate long-term contracts with producers and in the process gives them power to bargain for a lower price. On the other hand, there is little chance that a buyer will backward integrate into the production of minerals themselves due to the extensive capital requirements and specialized knowledge needed to enter the mining industry. This reduces buyer power to negotiate a lower price.

In a competitive market, buyers are often sensitive to the price of minerals. Buyers enjoy moderate power in the mining industry due to low switching costs, an undifferentiated product, and the bargaining power of large companies.

Power of Suppliers: Moderate

The power of suppliers to the mining industry is analyzed similarly to the power of buyers from the industry, in that the importance of price sensitivity and bargaining power (and their respective determinants) still apply. The key suppliers to the mining industry include equipment manufacturers, electricity suppliers, specialized labor, and landowners (frequently the federal or state government). Overall, supplier power within the mining and metals industry is present but manageable.

Given the historically low profit margins of the mining and metals industry, strong sensitivities exist to increases in operating costs, reducing suppliers' power. Additionally, given the specialized nature of heavy mining equipment, some suppliers would be hard-pressed to find additional customers outside of the mining industry. The mining industry exerts a level of buyer power over the producers of mining equipment that limits supplier power in this area.

Mining and metal production facilities require large amounts of electricity and often have no choice as to who their supplier is, creating supplier power for the power company servicing the mine and/or processing center. Another supplier that retains some power over the mining and metals industry is that of skilled labor. Good employees are critical in any market, but as mines become more technologically sophisticated and are often located in remote areas, skilled labor demands a higher wage.

If there is one input into the mining and metals industry for which significant bargaining power may be exercised, it is the resource of land. Minerals, and the ore in which they are contained, are only present in certain areas where specific geological conditions exist. If a land owner (or the government) does not agree to sell, lease, or otherwise allow a company to mine where the resource is located, the company cannot simply go to the next supplier.

Some producers in the mining and metals industry have vertically integrated and own the value chain from mine to finished product. Due to the extreme capital costs to own and operate a mine, most companies are not able to do this, but the potential for companies to backward integrate provides a means to counter supplier power.

Threat of New Entrants: Weak

The threat of new entrants into the mining and metals industry is weak and can be attributed to significant barriers to entry, including capital requirements and governmental regulations. Huge investments of capital are required to enter the industry, not only in investment in heavy machinery and infrastructure, but also to buy or lease vast tracts of land. Considering that these costs are in addition to up-front exploration costs, the total cost of starting a mine can easily reach into the hundreds of millions. Only those companies with vast financial resources can play this game.

Additionally, the process to obtain the legal right to mine is both cumbersome and time intensive, which requires a company that is both dedicated to the cause and well-versed in government bureaucracy at both the state and federal levels. The USGS provided an overview of the time required for a mine to begin production from initial discovery in a report in 2010, and the time varied from 5 years up to 50 years![99] Compliance with stringent environmental regulations adds to the operating costs once a mine comes on-line.

Threat of Substitutes: Weak

Metals are subject to the threat of substitution, but often one metal is substituted with another metal or alloy. This often occurs because the substitute metal is less costly to produce and the associated degradation in performance is acceptable. Some materials may be substituted for metal in certain applications with benefits such as lighter weight. However, substituting such materials may have performance costs and may require significant switching costs.

As technology and social pressures increase, recycling could act as a substitution threat to new production of metal. Facing growing demand, it can also serve as excess capacity. The mining and metal industries recognize this, and most companies are taking steps to incorporate recycling and recycled materials into their value chain. Overall, the threat of substitutes to the mining and metals industry is weak. This could change rapidly, however, if a breakthrough technology was developed that substituted a non-metal product for a widely used metal product.

Competitive Rivalry: Strong

Competitive rivalry within the mining and metals industry is strong. Price is often the only basis for competition as it is hard to differentiate products. This can lead to intense competition with low profit margins and high fixed costs.

Mining is a unique capital-intensive industry due to its high sunk costs. Unlike other industries that possess high fixed costs, the capital that is expended to mine for a commodity is not easily transferable.[100] The results in struggling firms staying in the market when they would otherwise divest and exit the industry. It is also important to note that not all companies are required to play by the same rules. Governments establish subsidies and import restrictions in an effort to support their own domestic production, and, in some cases, these policies allow a firm that would otherwise fail to continue operations. Policies such as these result in additional exit barriers that further increase competition.

Firm Behavior in the U.S. Mining Industry

The structure of the mining industry plays a leading role in driving firm behavior. At the same time, firms each make choices to establish competitive strategies within this environment. While business gurus extoll the need for strategies that "deliver greater value to customers," mining firms face the reality that most products are non-differentiated commodities.[101] In an industry of price-takers, firms find it impractical to change buyers' willingness to pay due to their low switching costs. Thus, many strategies devolve into price competitions. Facing strong competitive rivalries, with little to no means for product differentiation and low switching costs, successful firms establish competitive advantages by choosing where to mine, what to produce, and whether to be a leader or follower in mining innovation.

Choosing where to mine centers on ore quality, socio-political environments, and infrastructure impacts. Ore quality, combined with ease of extraction, provides sustained competitive advantages beyond operational efficiency. For two similar mine operations, the one generating more value for each load moved has a persistent advantage. As mines deplete the most economically viable reserves in one region, firms seek opportunities in new areas, including emerging economies.[102] Emerging economies present opportunities for reduced production costs with cheaper labor and lower environmental standards, but they have risks. Miners typically welcome economic incentives from foreign governments. However, mines are subject to disruption by special interest groups and changing government policies. Mining and water rights are closely negotiated and are often re-negotiated at inopportune times due to local pressures placed on host governments. With large initial capital investments and decades-long recapture times, firms seeking a competitive position must anticipate such issues. Successful firms establish competitive advantages by hiring and developing professionals in political and social disciplines to foresee and prevent problems. These consultants establish win-win relationships with governments and communities. Continued engagement by firms with host-nation stakeholders is critical as mining deposits are often wholly owned by national governments.

Firms can establish competitive advantages with other location-specific elements. Operations near ports and waterways see lower transportation costs when compared to operations in more access-restricted locations. Other similar location advantages can last for the life of a mine. Operating locations sometimes provide additional benefits, such as low energy prices or other infrastructure factors. Those factors may provide substantial cost advantages, but they may prove less enduring as well. Choosing what to produce involves mineral selection, co-product considerations, and horizontal or vertical integration. Mineral selection drives processing requirements. Firms with expertise in unique extraction or processing techniques find it beneficial to focus on those sectors, especially when processing involves further health, safety, and environmental regulations that add cost while increasing barriers to entry.

Another way mining firms position themselves is by choosing to lead or follow in innovation. While the benefits of innovation show up as efficiency improvements, choosing to lead innovation represents a strategic position as it puts a company at the forefront of pushing the productivity frontier and forcing competitors to adapt. Firms face choices to give up seemingly clearer short-term profits for potentially greater long-term profits. For example, one mining company dedicates a portion of its facilities to testing new equipment and processes without imposing its standard productivity requirements.[103] It accepts that some projects will fail and allows for greater risk-taking on a small scale, as the company discovers what new technologies work best for their operations.

Financial Performance of the U.S. Mining Industry

Mining is not for the faint of heart. It is a long-term industry where patient and flexible capital are key. Financial performance is cyclical as firms are price takers in a commodities market where there is little product differentiation. High entry and exit costs are further compounded by the strong supplier power held by governments. The most recent mining bust occurred in 2015 and is largely attributed to market oversaturation by Chinese mining firms which caused commodity prices to fall by more than twenty-five percent (25%). The undervaluation of the Chinese yuan had the additional effect of making imports by Chinese businesses more costly while also increasing the viability of Chinese manufacturers of mineral end-products.[104]

U.S. firms experienced large decrease in commodity prices, Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA), a universal measure for a company's operating profitability, dropped by thirty-nine percent (39%) to $91 billion. Mining firms rushed to save capital. They stopped investing in new operations and limited cash expenditures as much as possible. As a result, the Return on Capital Employed (ROCE) decreased to a negative four percent (-4%). On average, dividend payouts to shareholders were cut in half.[105] Notably, however, dividends were still paid out to satisfy investors. Although mining is a long-term industry, when faced with large decreases in operating profits investors viewed debt burdens as unaffordable and limited their investment capital. These discouraged investors left the mining sector in droves.

Faced with liquidity squeezes from shareholders and already overleveraged in debt, firms were forced to focus on paying down their debt through any means necessary to stay afloat. In addition to mortgaging the future by halting investment in new exploration, they sold assets to increase their liquidity to pay down their debts. By the end of 2015, the market capitalization of the top forty mining companies had dropped by thirty-seven percent (37%) or $297 billion.[106]

The year 2018 marked the height of recovery of the mining industry from its 2015 bust. Continued growth in commodity prices increased revenue growth by eight percent (8%). The oversaturation of supply had subsided as unprofitable firms either went out of business or mothballed their mines. The benefits of cost-cutting during lean years also increased earnings. EBITDA was valued at $165 billion, a 181% increase from the 2015 bust of $91 billion. Return on Capital Employed was 10%, the highest since the bust. 2018 also had the distinction of having the highest dividend payout, $43 billion, since Price Waterhouse Cooper (PwC) started measuring the mining performance of the top forty mining firms in 2003.[107]

Market forces coupled with government sponsorship of the mining industry leads to overall poor economic performance in the metals and mining sector. Mining firms know this and continue to pay dividends even during bust cycles. If the United States wants to promote mining it must take a pro-active role to encourage investment into the industry.

Current Business Risks and Trends in Mining and Metals

This section, utilizing a Strength, Weakness, Opportunity, and Threat (SWOT) analysis, examines the mining and metals industry in 2020. It categorizes '*Innovation as a Strength*,' '*Workforce as a Weakness*,' '*Green Economy Demand as an Opportunity*,' and '*License to Operate as a Threat*.' It is essential to consider these industry-specific equities contemporaneously and within a business ecosystem nexus, a "…network of organizations – including suppliers, distributors, customers, competitors, government agencies, and so on – involved in the delivery of a specific product or service through both competition and cooperation."[108] The analysis utilized

commercial mining and metals expert consultations as the primary source for the information, analysis, and synthesis within.

Innovation as a *Strength* (See Appendix VI for essay on innovation)

Innovation is an important vehicle for value creation in metal and mining industries, with a wave of technology-based modernization activities offering the opportunity to increase supply chain productivity and efficiencies. Burgeoning advancements at all stages of the industry's value chain, coupled with the abundance of U.S. technology companies, uniquely posture the segment to meet Call to Action #1 from the *Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*: "Advance Transformational Research, Development, and Deployment Across Critical Mineral Supply Chains."[109]

Favorably, the 2020 Bloomberg Innovation Index notes that the U.S. leads the world in technology company density and patent activity.[110] Technology-based innovation will define global competition in the industry. The World Economic Forum exhorted that digital transformation in automation, robotics, operational hardware, integrated enterprise platforms and ecosystems, as well as next-generation analytics and decision support could bring about $425 billion in collective value through 2025.[111] According to KPMG International Cooperative, a consultancy with clients in 147 countries, they "…expect mining companies will increasingly adopt emerging technologies to transform their operations in order to gain benefits such as reduced costs, improved health and safety of workers, minimized environmental impacts and a better understanding of the ore body."[112]

In a survey of 130 mining industry executives regarding opportunities to move up the technology maturity curve, 73% perceived technology as an opportunity versus a threat, 42% believed they were actively disrupting the market, and 33% expected disruption to weaken or ultimately eliminate competitors failing to transform.[113] White & Case, an international law firm, published its 2020 mining and metals market sentiment survey that asked industry participants, "what will be the biggest driver of innovation in mining?"[114] The resulting top responses were cost pressure (39%), investor pressure (23.7%), government regulation (13.1%), and purchaser power (10.5%).[115] Deloitte's report, *Tracking the Trends 2019: The Top 10 Issues Transforming the Future of Mining*, cited water as an example of cost pressure-driven research and development as "concerns around water quantity and quality are also exacting financial, operational, and reputational tolls."[116] The Climate Control Project advised that by 2030 water scarcities could jeopardize 25% of mining production, putting at risk $50 billion in annual revenues.[117]

Workforce as a *Weakness* (See Appendix VII for essay on human capital)

This section spotlights the challenge of the domestic metal and mining industry's workforce, its state of atrophy, and its skills gap predicament. This concern aligns with Call to Action #6 from the *Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals*: "Grow the American Critical Minerals Workforce."[118] To further capitalize on the nation's innovation base and posture, it will require a labor force capable of meeting the growing demand for a green economy. Policy creation must consider talent management trends that include the ubiquity of technology, shifting demographics, and global competition for specialized human capital. As described in *Mining Explained*, "[m]ineral exploration and mining is now a business that calls for highly skilled individuals to work as a team, using powerful, often computerized, exploratory and mining equipment."[119] Moreover, the highly skilled individuals within the U.S. mining industry are mostly nearing 50 years of age, with much of that workforce set to retire within

15 years.[120] The World Economic Forum, in its white paper, *Digital Transformation Initiative: Mining and Metals Industry*, poignantly noted that, while the specialized labor pool is dwindling and becoming more costly, "[t]he digital worker of tomorrow must be engaged and prepared today."[121] With only one mining and metals school specializing in rare earth studies, the U.S. is at serious risk of failing to produce the next generation of mining engineers and metallurgists.[122]

All of which would leave the nation dependent on foreign sources with damning prospects for homegrown mining and metals companies. For as David S. Abraham wrote in *The Elements of Power*, "[i]nnovations in processing, designed by educated and skilled workers, can bring far more materials to the market, more cheaply, than can mining companies just searching for new deposits."[123] Deloitte, in its report, *Tracking the Trends 2020: Leading from the Front*, suggested that strategic workforce planning "can help organizations to understand which roles will be affected; what new roles, capabilities, and skills will be required; and therefore what talent and workforce strategies should be deployed."[124] It is also imperative to design diversity and inclusion into strategic workforce planning considerations. Research suggests that, in doing so, companies position themselves to thrive and outperform their rivals. Studies found that the most diverse and inclusive companies are twice as likely to meet or exceed financial targets, three times as likely to be high performing, and six-time as likely to be agile and innovative.[125]

Green Economy Demand as an *Opportunity*

The global demand for a green economy is an opportunity for the mining and metals industry. Manish Bapna and John Talberth, both with the World Resources Institute, described this nascent category of demand:

> A Green Economy can be thought of as an alternative vision for growth and development; one that can generate growth and improvements in people's lives in ways consistent with advancing economic, environmental and social well-being.[126]

The consensus for transformation creates industry incentives to transform and an imperative for legislators to generate policies that champion domestic comparative advantages in the global marketplace. Baker & Mackenzie, a multinational law firm with expertise in global economic challenges, succinctly advised that "[a]s these developments play out, the countries that will benefit most are those with proactive government policy."[127] The consultancy goes on to note that global competitors, traditional companies, as well as new entrants, are enthusiastically charging into the green economy space; "[a]s these manufacturers are consolidating their supply chains, countries around the world are competing to capture investments at different stages of the production process."[128] The exodus from fossil fuel-based trade activities to an alternative energy-centric economy is a watershed moment for the mining and metals industry.

David S. Abraham, in *The Elements of Power*, submitted that "[i]f using less energy and therefore less carbon dioxide (CO_2) is a qualification for green technology, then the mining and processing of minor metals may be the one of greenest technologies of them all."[129] That is likely the case in a 'new energy' world powered by renewable and electrified means. The proliferation of solar and wind-based power generation and the rising prevalence of electric vehicle use will create a consumer-led shift and surge in demand for minerals. Baker & Mackenzie proposed that "[t]he increase in battery demand (and the expectation of that increased demand) creates other opportunities, including demand for industrial minerals used in batteries, such as graphite, lithium, nickel, cobalt, manganese, aluminum, vanadium and rare earth metals."[130] While traditional

resource exporters are well-positioned to meet the rising demand for raw materials, the U.S. must consider government policy meant to encourage domestic companies to capture more of the supply chain from exploration and mining and onto R&D and production.

License to Operate as a *Threat*

For a risk to rise to the level of threat, the danger must present the formidable prospect of creating ruinous harm to the viability of commerce within its marketplace. That threat, for the mining and metals industry, is its license to operate. According to Ernst & Young (EY), a global leader in advisory services, license to operate is the #1 business risk facing the mining and metals sector in 2020.[131] allBusiness, citing a Barron's Education Series, defines license to operate as a:

> Grant of permission to undertake a trade or carry out a business activity, subject to regulation or supervision by the licensing authority. Licenses are granted by state or federal agencies, and also by private concerns, as when a business authorizes another business to use its name as a franchise operator. Licenses granted by government authority imply professional competence and ability to meet certain standards set by law or regulation.[132]

Furthermore, it is an amalgam of meeting formal regulatory requirements along with communal expectations. Investopedia defines it as "…the ongoing acceptance of a company or industry's standard business practices and operating procedures by its employees, stakeholders, and the general public."[133] Regardless of a formal license to operate, without the legitimacy, credibility, and the trust of a social license to operate, industry business ventures are sure to fail. Researchers Kieren Moffat and Airhong Zhang submit that "[i]nstances of mining developments being delayed, interrupted, and even shut down due to public opposition have been extensively documented."[134]

Accordingly, legislation should aim to encourage corporate-community relationship building while rebranding the mining and metals industry's image. Undoubtedly, environmental, social, and government (ESG) parities are at the forefront of industry concern. Experts concede that this operating environment is complex and evolving. Jennifer Prillaman of social innovation advisory The Palladium Group posits that, "[g]overnments, consumers, and even shareholders are pressuring these companies to be more innovative in their environmental, social, and governance (ESG) efforts, to engage meaningfully in their communities where they operate, and to create opportunities for social and economic development."[135] The author further suggests that business-level collaborations are only significant in the form of market-oriented ventures that yield both tangible social and financial gains; "[c]ommunities are asking for a different kind of relationship. They want royalties, business partnerships, and skin in the game."[136] ESG missteps, by either government, industry, or agents of both, could result in catastrophic consequences concerning the outlook for domestic mining and metals industries.

Industrial Mining Policy Shaping the Great Power Competition

The U.S. is increasingly import reliant for a number of critical minerals, including 39 which are sourced from China and Russia – the two main countries involved in great power competition with the U.S.[137] Since both countries "are…onerous to deal with geopolitically and each has sufficient mining output to be its own cartel," many fear that the U.S.' mineral dependence puts the country at risk of being held hostage by our adversaries for minerals critical to our national

security and economic prosperity.[138] Thus, it is important to understand China and Russia's strategic material industrial policies for mineral dominance to effectively anticipate and counter any threats that may arise from those policies or a shock to the supply of critical minerals.

Chinese Industrial Policy in Strategic Materials

In assessing Chinese industrial policy, it is essential to understand to whom one refers when using the term "China." When the Chinese State Council/President set out a vision, several different government departments and agencies, state-owned and private enterprises work together to achieve the same objectives.[139] One must give credit to China for a series of meaningful policies its government has enacted in a deliberate, calculated, and strategic manner to achieve its current position of strength in strategic materials.

The global community welcomed Chinese economic reforms in the late 1970s. While then-premier Deng Xiaoping made his lofty strategic materials production policies clear, China was still an importer of such products and posed little threat to industrialized nations.[140] However, China's accession to the World Trade Organization in 2001[141] unleashed a two-decade period of double-digit growth in GDP, making it the undisputed strategic material powerhouse of the world. Chinese policies, combined with massive state capital funding and US complacency, set the stage for China to wield global monopolistic power of strategic materials in ways the world has never known.

First, China developed and exploited its vast domestic resources. China's largest strategic materials mine is the Bayan Obo in Inner Mongolia that accounts for 45 percent of world production alone. The Chinese government invested heavily in research and development since the 1960s and now benefits from almost 60 years of scientific advances up and down the mining value chain.

Second, China offered generous tax incentives to entice downstream consumers of strategic materials such as high-tech electronics producers. Furthermore, foreign investors wanting to use strategic materials in their finished products had to use Chinese materials or enter into a joint venture with Chinese companies. As a result, many foreign producers of strategic materials and their associated products could not compete against Chinese producers and eventually left the industry, went bankrupt, or were relegated to an insignificant portion of market share.[142]

Third, of those foreign strategic materials producers that remained competitive, Chinese state-owned enterprises sought to invest in or outright acquire them. For example, as early as the 1990s, China realized the potential for rare earth permanent magnets and found an opportunity to control the market. In what turned out to be one of the most notorious strategic material deals in U.S. history, the U.S. government approved the Chinese acquisition of Magnaquench – General Motors' magnet producing subsidiary. The Chinese eventually shut down the company and moved the entire business to China. As Sophia Kalantzakos correctly asserts, "The deal was a strategic mistake on the part of the United States, because when the business left, so did the technology. Within a decade, the bulk of the magnet industry had moved to China."[143]

Today, China continues to demonstrate a willingness to use strategic material supplies as geopolitical leverage. During a recent trade dispute with the U.S., Chinese President Xi signaled that his government was willing to disrupt strategic materials supply during a very public visit to rare earth production facilities. Official Chinese media outlets also messaged China's intention to seriously evaluate its policies on strategic materials exports. As a result of the recent U.S./China tariff escalation, Beijing raised tariffs to 25 percent on the ore that U.S.-based strategic materials companies send to China for processing.[144]

While opinions abound on what China's much-touted Belt and Road Initiative (BRI) is or is not, two initiatives are clear. First, the BRI serves to create external markets for excess industrial capacity. Second, it seeks opportunities for China to influence or control foreign natural resources and infrastructure. The second initiative has garnered more international attention – the hundreds of billions of dollars China is investing in developing nations' infrastructure around the world. Despite abundant natural resources of its own, China must still use many strategic materials to sustain the current needs and future growth of its country. A recent *Foreign Policy* analytical report observed that, "With global demand for strategic materials projected at a compound average growth rate of more than 17 percent to 2025, a supply crunch is likely approaching—and China is already securing other nations' supplies."[145] Moreover, China tends to target politically unstable countries with markets that lack transparency.[146] Some recent examples of Chinese interests include countries in Africa and South America.

It would be unfair to suggest that China isn't entitled to act in its self-interest like any other nation with global aspirations. As Ned Mamula observes, "China can hardly be blamed for its clever use of global mineral resources. Decades of unsustainable U.S. mineral resource policies contributed mightily to its success and our nation's present state of wild over-reliance of many critical minerals."[147] Nevertheless, growing evidence suggests that China has outsized global ambitions and the power to wage devastating economic warfare against the U.S. if it chose to do so. Indeed, the current coronavirus pandemic serves as a stark warning regarding over-reliance on China for critical supplies.

Russian Industrial Policy in Strategic Materials

Since 1992, Russia has developed a set of laws, regulatory bodies, and policies aimed at protecting and managing its natural resources. The Russian mining and minerals industrial sector faces significant challenges, including attracting human capital, obtaining permits for exploration, and enticing investment, especially since the majority of mining companies are owned by Russian citizens—typically the Russian oligarchs—and not state owned enterprises. In response to such challenges, Russia issued the *Strategy of the Geological Industry Development until 2030* in 2012 to rectify those issues.[148]

The strategy lays out plans to increase exploration of the continental shelf and inland water areas by 50% by 2020 and then 70% by 2030. It sets an annual goal of a 7.5% increase in the expansion of small-scale geological surveys and targets an 80% increase in new exploration and mining licenses by 2020. The strategy discusses the provision of "geological organizations with highly qualified specialists" and "ensuring growth in funding from extra-budgetary sources due to the increase of investment attractiveness of exploration work in relation to the level reached…in 2020 to 40%, and in 2030 to 50%."[149] All of these initiatives are centered around increasing productivity and output in the mining and mineral sector.

Furthermore, in order to protect its competitive advantage in mineral wealth, all mineral resources that are located underground belong to the Russian Federation (whereupon they transfer ownership to whomever holds a subsoil license for extraction). Russia also classifies certain mineral deposits as *deposits of federal significance*. These deposits of federal significance include "uranium…rare earth elements of the ytrrium group, nickel, cobalt, tantalum, niobium, beryllium, lithium, diamond deposits or ore deposits of the platinum group metals [PGM]…[and/or those that] are located in internal waters, territorial waters or on the continental shelf of the Russian Federation."[150] This is directly tied to Russia's Arctic strategy and consistent with the Federation's

continued attempts to expand Russia's continental shelf in the Arctic via claims to the Lomonosov Ridge and the Mendeleev Rise.[151]

The Russian government also classifies information on PGMs, nickel, cobalt, lithium and the production of "strategic natural resources in the Russian Federation as a whole" as state secrets and therefore subject to "state secrecy legislation."[152] For years it has been difficult to get accurate numbers of reserves for various minerals, both because Russia did not release information and because it still uses the old Soviet Union classification system which is not the standardized one used by Western countries and firms.[153]

Many argue that Russia's abundance of natural resources, particularly in minerals deemed "critical" to the U.S. – such as asbestos, niobium, scandium, vanadium, potash, titanium (sponge), chromium, germanium, diamond (industrial dust, grit and powder), silicon, platinum and palladium – provides Russia with "enormous geopolitical leverage," since the U.S. is heavily import reliant for these strategic materials.[154] Concerned with what could happen to world markets if Russia's supply of certain minerals was cut off, the USGS published a study in 2017 (based on 2014 data) which analyzed a halt in Russia's production of Aluminum, Nickel, Palladium, Platinum, Potash and Titanium mill products.[155] What they found was illuminating: "The overall effect of a supply shock is likely to be quite modest…taken alone, Russia's share in the world production of a particular commodity is not necessarily indicative of the size of potential impacts resulting from a supply shock; other factors, such as prices, domestic production, and the structure of international commodity flows were found to be important as well."[156]

World markets got a preview of a Russian induced supply shock in March 2019 when Russia banned exports of "scrap and tailings of precious metals from May until November." By restricting supply, Russia drove the spot price of palladium up to $1,592 an ounce.[157] Thankfully, the U.S. also imports much of its platinum and palladium from South Africa, where "large projects on the horizon in southern Africa with high palladium content, such as Platreef and Waterberg" could increase supply and bring prices down in the future.[158] Thus, as long as other countries continue to develop, extract and sell critical minerals, Russia's policies to use its natural resources as leverage against the U.S. will be limited in scope.

Policy Recommendations to Enhance National Security

Any government intervention in markets carries risks of unintended consequences. Therefore, the government should only execute policies to intervene when it identifies specific market failures of significant magnitude and particularly deleterious nature. Moreover, government policy actions should allow market forces to work wherever possible and avoid picking winners or choosing specific solutions. Instead, government policy should strive to create more effective market efficiency and allow competitive forces in the market to produce optimal solutions. The following policy recommendations therefore seek to apply this approach to correct mining and mineral market failures. The identified failures and recommendations are grouped into three bins: Shaping market forces to correct imperfect competition, Addressing market inefficiencies due to externalities, and Addressing market inefficiencies related to public good characteristics.

Shape Market Forces to Correct Imperfect Competition and Increase Participation in the Mining Sector

1) Reduce Barriers to Entry and Exit.

   High upfront costs, long recoup times, and high exit costs reduce participation in the U.S. mining industry. To reduce upfront costs, the Federal government should collaborate with states to allow greater pooling of reclamation bonds that firms must provide as insurance against environmental remediation.

2) Dampen the Impacts of Market Volatility in Mineral Prices.

   Price volatility and the challenges of market forecasting greatly impact profitability in the mining industry, contributing to a return on invested capital (ROIC) well below average industry levels in the U.S. To reduce risk associated with this volatility, the Federal government should allow mining firms to carry tax write-offs forward up to 20 years, for all industry stages from mining through mineral processing.

   The Federal government should further smooth price volatility by entering into long-term contracts with U.S. companies to provide critical minerals for the National Strategic Stockpile. When possible, such contracts should be spread across multiple mining companies.

3) Modernize Rental Permitting Payment Structure.

   Rental rates on federal lands are too low and encourage speculative miners who "claim grab" without ever intending to mine. The federal government should adopt local state government payment structures that incentivize miners into production. In Texas, the yearly rental rate for an oil extraction lease increases by five hundred percent (500%) if production has not started after two years. Additionally, the royalty rate increases every two years by two percent (2%) if production has not started. If firms increase their production, rental rates and royalties will decrease over time.[159] To further mitigate speculation, Texas requires upfront payment of all rental fees for the life of the lease. This helps filter-out speculators in commodity markets who only look to re-sale leases when markets turn upward.

4) Ensure Accountability in Federal Mining Permitting Process.

   The United States possesses an estimated $6.2 trillion worth of mineral reserves, yet, it is hampered by one of the world's longest permitting processes. On average, a major mining project takes seven to ten (7-10) years before approval to begin mineral extraction is given.[160] This is unacceptable when other allied countries can approve mining permits in as little as four months to one year.[161]

   In order to improve the mining permitting review process, the United States' federal government agencies responsible for reviewing mining plans must first capture, measure and analyze their performance. Failure by the Bureau of Land Management and the

Forestry Service to provide accurate data on the time to complete federal mining permit review to support a Congressionally requested GAO report is unacceptable.[162]

To hold the Executive branch accountable, Congress should enact legislation that approves federal mining permits if an approval or a detailed denial with actionable remediations is not provided by executive agencies within one-hundred and eighty (180) days. Deferrals could be granted to the permitting recommendation timeline for extenuating circumstances. Additionally, the time would stop once the agency returned the package to industry for actionable remediations. Holding federal agencies accountable through a stringent timeline will give them the flexibility to adopt strategies found in more productive allied countries.

To decrease the impact on both the Executive agencies and industry, the USG may create a website where industry can submit all of its filing requirements to the USG and where the agencies may provide information on all regulatory requirements. The agencies could then access the same site to coordinate their reviews, provide guidance to industry, and educate the public on each agency's appeal procedures. This would consolidate and streamline the current system of separate websites for each agency and regulatory requirement.

Address Market Inefficiencies due to Externalities

5) Tax Imports to Internalize External Costs.

Minerals and mineral products imported from China and many other countries have market prices below marginal social costs. This is due to less-stringent environmental and safety requirements as well as government subsidies for mineral production. The Federal government cannot directly regulate production as it does with operations in the U.S., but it can tax those imports sufficiently to align prices with true social cost and simultaneously create a more level playing field for U.S. production. Given this objective, import tariffs should vary based on product origin and the associated levels of environmental, safety, and government subsidies contributing to the mineral production cost.

6) Establish a Modernized Federal Royalty Structure for Mineral Extraction.

Since 1872, mining firms have taken more than $300 billion worth of minerals from federal public lands without paying any federal royalties.[163] The United States requires federal royalties for coal, oil and natural gas extraction that occurs both on public land and offshore, however, there has never been a federal royalty for mineral extraction on public lands. This is a missed opportunity, as royalties "represent one of the federal government's largest nontax sources of revenue." In 2016 alone, the federal government received over $2 billion in coal, oil and natural gas extraction royalties. Half of these proceeds were shared with the state government in which the commodity was extracted.[164]

In addition to charging royalties on state lands, state governments charge taxes on federal lands, called functional royalties, and do not share any of these proceeds with the federal government. The federal government should impose royalties without placing an

unnecessary burden on mining firms. By imposing a cap on royalty percentage charge, the federal government would take the difference between the state's royalty percentage charge and the cap. For instance, if the cap is 10% and the state charges 5%, the government would claim 5%. If the state charges 7%, the government would claim the additional 3%, equating to a 10% overall royalty charge. The federal government must also modernize royalty structure to make it scalable to market conditions while providing incentives that protect federal lands.

The natural onshore oil and natural gas royalty has remained unchanged at twelve and a half percent (12.5%) of gross revenue since the 1920s and is far less than the royalty rate charged by state governments. Failure by the federal government to have the federal royalty rate match the modern state rates of 16.67% or 18.75% have resulted in lost revenue of $490 and $730 million to state governments. Implementing a sliding royalty scale that is tied to the price of the commodity when it is sold will ensure that the federal government shares in the rewards during a commodity boom cycle and the pain during a commodity bust cycle. This sliding royalty scale would only apply to the federal portion of the royalty.

To help encourage exploration and extraction, the federal government should charge a lower royalty in areas that are more speculative and a higher rate in more proven areas to encourage large scale resource extraction by proven mining firms.[165] Higher rates could also be charged to mine in more environmental sensitive areas with proceeds allocated to a federal fund that would be used to reclaim and clean up abandoned mines.[166]

Federal mining royalties should be used to increase the incentives for mining and must be kept in a Congressional mandated account that is exclusively used for mining. Funds would be used to subsidize the costs of mining bonds, increase the budgets of federal agencies to expedite mining permits and used as an environmental fund to clean up abandon mines, which would help offset the $2.6 billion spent by taxpayers to clean up abandoned mines between 1998 and 2007 alone. A certain percentage of monies in the account could be used to increase the government stockpile of minerals and the proceeds from mineral sales could be reinvested into the account.

Address Market Inefficiencies Impacting Public Goods

7) Invest in Mining Research and Development.

Mining firms tend to underinvest in research and development because capturing the value that results from basic research supporting extraction and processing is difficult. Instead, such basic research has a public good nature, generating benefits that extend inevitably and significantly beyond the entity actually conducting the research. The Federal government, therefore, should provide additional funding for basic mining research, especially targeting new technologies that are more efficient and/or environmentally friendly. The Federal government should also increase tax write-offs for mining-directed research and development spending by firms. Finally, the U.S. should reinstate the U.S. Bureau of Mines (USBM), which would prioritize and coordinate mining research support among government agencies, National Laboratories, industry, and academia.

8) Reduce Leverage of Hostile Competitors.

China has demonstrated its willingness to restrict exports of critical minerals such as REEs to put economic pressure on competitors. To mitigate and manage this leverage, the U.S. should maintain its National Strategic Stockpile of critical materials and ensure these materials are in usable forms and that the stockpile is ready for rapid activation. The Federal government should also provide critical mineral inventory tax write-offs that incentivize private firms to retain on-hand or ready stocks sufficient for one year of production.

To avoid future situations such as the acquisition and then closure of the Magnequench rare earth firm by the Chinese, the Agency Head of the Department of the Interior should be added to the committee composition of CFIUS. This would ensure qualified "commodity specialists at the USGS, as well as mineral and mining experts at BLM and in the Office of the Secretary of the Interior" reviewed foreign direct investment that could result in unequal access to U.S. natural resources, and/or damage the U.S.' capacity or capability to meet national or economic security needs.[167]

9) Require Mandatory Geological Reporting.

Many countries have robust mandatory reporting requirements for entities who obtain mineral exploration concessions. In Chile, exploration concessions are only valid for two years with a possible two-year extension and, when the exploration concession ends, the entities are required to provide detailed geological survey reports to Chile's Servicio Nacional de Geología y Minería (SERNAGEOMIN). Once reviewed for accuracy, the SERNAGEOMIN publishes the information online and free to the public to encourage application for mining production concessions. By requiring detailed geological reports and making them public, Chile reduces the number of speculative miners who "claim grab" without ever intending to mine and can more easily review mining plans submitted by mining firms. In Australia, annual activity and geophysical survey reports are required for both exploration and mining titles.[168] The information is turned-over to the Australian States, which have the "responsibility for acquiring, storing and distributing this information." This ensures that the country as a whole obtains critical information regarding mineral deposits and production capacity.

The United States should adopt a similar approach and make mandatory reporting a condition of acceptance prior to approving a Plan of Operation to mine on federal lands. Doing so would help offset the costs of mapping and cataloging deposits, inform future exploration and production efforts while reducing the number of speculative miners who never intend to mine productive lands. This recommendation also carries acknowledgement that the U.S. Government may need to sponsor more mineral exploration, as individual firms could be less incentivized to devote resources when required to share the information they obtain.

10) Support Development of Mining Industry Human Capital.

Modern mines in the U.S. rely more heavily on skilled trades and STEM graduates than their historical counterparts. To remain competitive, the U.S. should promote advanced

worker training and professional STEM programs. The Federal government, through the reinstated USBM, should increase mining-related STEM scholarships. The USBM should consider targeting individuals already working in relatively lower-level mining jobs who wish to advance to professional positions. The Federal government should also increase the number of visas offered to foreign STEM graduates to come work in the U.S. mining industry.

11) Increase Public Understanding of Mineral Importance.

Most Americans do not appreciate the importance of mining to U.S. economic security and the transition to a low carbon economy. Better public awareness could substantially increase the support for U.S. mining as well as interests in mining research, development, and professional careers. Such support could lead to fewer legal challenges to responsible mining proposals and a more competitive mining industry. The Department of Commerce or reinstated USBM should promote a public awareness campaign focused on the improvements to health, safety, and environmental impacts, while acknowledging the risks. The campaign should also emphasize the need for specialty minerals in the development and deployment of low-carbon energy solutions, as well as the outsourcing of environmental damage currently taking place in many developing countries. Finally, public education should include changes to junior high and high school earth sciences courses to include information on the uses and importance of minerals in wind, solar, tidal, and other low carbon energy sources. Such efforts will encourage people to consider mining jobs less in the historical context and more in the modern, advanced technology context.

12) Coordinate Mineral Policies with Like-minded Nations.

Establish a new initiative - the Rare Earth Minerals Initiative (REMI) – to demand transparency, rule of law, anti-corruption measures, open markets, and respect for labor and environmental standards. While the U.S. participates in current efforts to address these issues and promote good governance, they do not go far enough. The United States, Japan, the European Union and South Korea should be encouraged to join as the key consumer states, while Australia, Canada, Brazil and others should join as key provider states. REMI states would coordinate approaches to developing more diversified supply chains and reduce leverage of hostile states. REMI states should coordinate research and development efforts, establish secure supply and purchase agreements for critical minerals, and support the mobility of mining related human capital. REMI states should also consider requiring companies working with rare earths or other critical minerals to obtain supplies only from producer states that can meet REMI standards.

Conclusions

The plight of the American mining and metals industry is a common story in the United States. Similar to manufacturing, what once was a booming industry contributing significantly to the GDP, has now tapered off. Mines have closed, jobs have moved overseas. Even when mining operations resume for certain materials (such as the rare earth element mine in Mountain Pass, California), it remains economically unfeasible or environmentally undesirable to undertake certain processes within the value chain, such as mineral processing, domestically. Instead, the

U.S. has turned from one of the world's premier mining and exporters of raw materials to an importer heavily reliant on trading partners for 62 mineral commodities.[169] Further exacerbating the problem is that the U.S. imports many of those commodities from major competitors or adversaries such as China and Russia.

The lack of domestic mining capabilities and import reliance poses a considerable threat to the nation's economic and national security. Without strategic materials, U.S. firms cannot produce the goods and technologies that make everyone's lives more sustainable and keep us safe from those who would do us harm. Thus, developing a vibrant domestic mining industry is crucial to the U.S.'s ability to shore up the strategic material supply chain.

For better or worse, the government cannot solely rely on the free market to generate sufficient investment in the domestic mining industry. There is a need for some level of government intervention to correct market failures; intervention does not mean the government should pick winners or losers. It simply means applying a whole of government approach to shape activities that would spur growth in the industry, whether that is protecting the industry from predatory foreign investment or re-instituting a government agency to shepherd our way back to greater mineral independence.

That said, it is unwise to think that the U.S. can simply dig its way out of our mineral dependence on other countries. The global economy has made it easier and cheaper for the U.S. to obtain the raw material from abroad, and cost savings will always play a factor in what sectors/goods companies choose among to either make, buy, or invest. However, if the U.S. does decide to import certain metals and minerals, then it should do so from countries that are our allies, not our competitors or adversaries who could use that leverage against us in the geopolitical arena. One solution already underway is the bilateral agreements with partner nations for certain minerals. Those should be expanded as much as possible with as many nations that want to work with the U.S.

Several limiting constraints on the government's ability to put more of those agreements in place center around resources—time, personnel, and funding. Those constraints are not unique to international trade or diplomacy. Certainly, the success of many of the recommendations outlined in this paper will depend on the availability of funding and personnel. That is why leadership at the local, state, and federal levels is required to craft a comprehensive message to the American people explaining why the U.S. cannot afford (both from an economic as well as national security perspective) to rely on foreign nations to supply critical material continually.

Without the support of the American people, Congress, the Executive Branch, and even private industry cannot layout or execute a roadmap to obtaining a healthy, vibrant domestic mining industry. Obtaining support is the only way to overcome the various social, ethical, and environmental concerns that linger from a less than stellar history of mining in this country. Furthermore, mining has evolved into a capital intensive, highly skilled industry with a long and arduous exploration and permitting process. The U.S.'s ability to surge or mobilize in the case of an event on the scale of the COVID-19 pandemic is extremely limited. The budget impacts that are coming as a result of the COVID-19 stimulus packages will impact all sectors and agencies throughout the nation. As a result, the hard choices this country will need to make in terms of stockpiling, investment, education, military weapons/assets, healthcare, and combatting homelessness, will make it harder than ever to drum up support for the domestic mining industry. The mining industry requires a significant amount of investment necessary to turn a declining industry into one that capitalizes on America's wealth of natural resources. Without it, the U.S. will lose out on a pivotal chance to secure this nation's economic future and national security.

APPENDICES

Appendix I – Acronym List

AFRL – Air Force Research Laboratory

BRI – Belt and Road Initiative

CO2 – Carbon Dioxide

COVID-19 – Coronavirus

CFIUS – Committee on Foreign Investment in the United States

DLA – Defense Logistics Agency

DPA – Defense Production Act

DPAC – Defense Production Act Committee

ESG - Environmental, Social, and Government (ESG)

EY – Ernst & Young

EBITDA – Earnings Before Interest, Taxes, Depreciation and Amortization

EPA – Environmental Protection Agency

GAO – Government Accountability Office

GDP – Gross Domestic Product

IBAS – Industrial Base Analysis and Sustainment

MIBP – Manufacturing and Industrial Base Policy

ManTech – Manufacturing Technology

MIC – Market Impact Committee

NDS – National Defense Stockpile

NEPA – National Environmental Policy Act (NEPA)

NRC – National Resource Council

PGM – Platinum group metals

POTUS – President of the United States

REE – Rare Earth Minerals

REMI – Rare Earth Minerals Initiative

ROCE – Return on Capital Employed

ROIC – Return on Invested Capital

R&D – Research and Development

SERNAGEOMIN – Servicio Nacional de Geología y Minería

SEPA – State Environmental Protection Act

STEM – Science, Technology, Engineering, and Math

STRATMAT – Strategic Materials

SWOT – Strength, Weakness, Opportunity, and Threat

U.S. – United States

USBM – Bureau of Mines

U.S.C. – United States Code

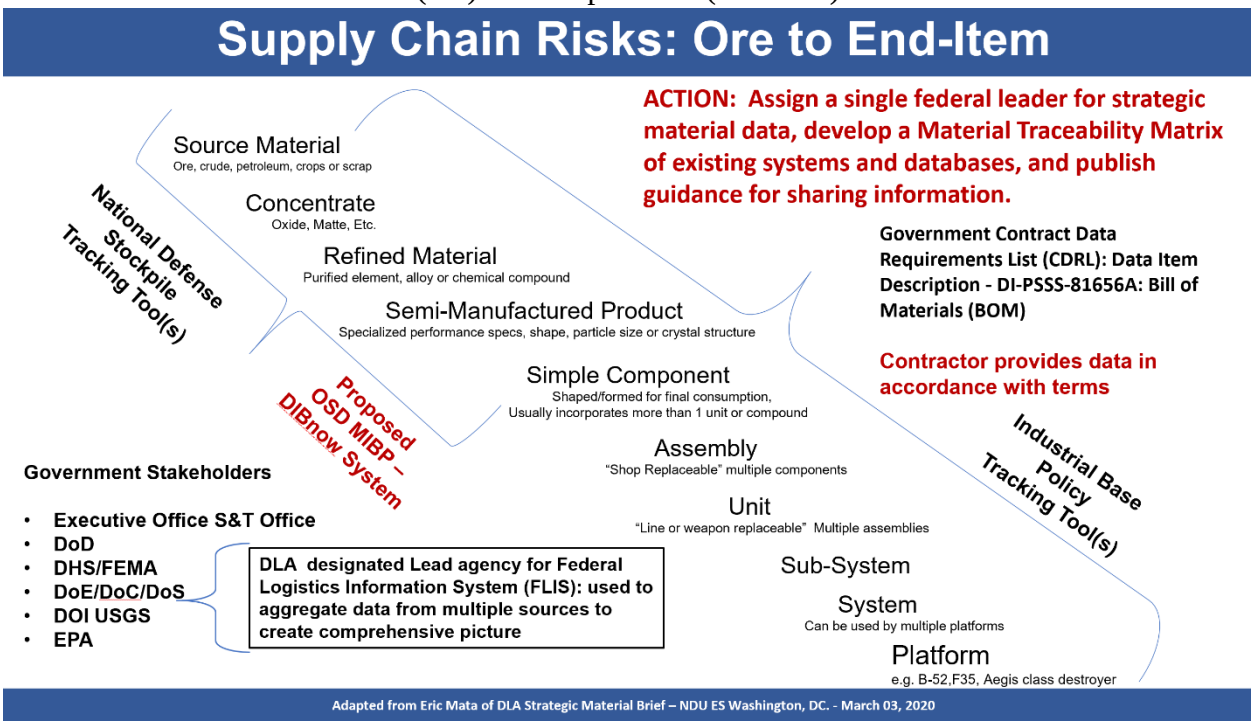
USG – U. S. Government

USGS – United States Geological Survey

WPB – War Production Board

Appendix II – Supply Chain Risks Essay

The GAO recommended that the OSD Manufacturing and Industrial Base Policy (MIBP), "improve data collection and analysis [and] determine a solution to make better use of existing lower-tier supplier information from program offices." To illustrate this challenge in strategic materials, The figure below depicts the supply risks of critical materials and highlights the number of levels between raw materials (ore) and the platform (end-item).



The end-to-end process from mining ore to separating, processing, and producing materials in an environmentally safe operation costs hundreds of millions (if not billions) of dollars for infrastructure, energy, labor, and permits. As highlighted in the case of REEs, even having domestic ore reserves and the functional capacity to mine and extract may be insufficient for supply chain security, given the inability to fully process the ore in the U.S.[170] Note that MP Materials purchased the Mountain Pass rare earth mine in 2017 after Molycorp filed for bankruptcy and closed the mine in 2015, yet the key factors that contributed to the mine closure and bankruptcy then continue to increase risks now. These factors include significant capital investments for infrastructure and equipment to open, operate, or modify existing mining or processing facilities.

In terms of industrial security, two U.S.-based venture capital firms are majority owners of MP Materials, however a Chinese firm, Leshan Shenghe Rare Earth Company, has a non-voting minority interest in the Mountain Pass mine." For some observers, this raises a flag of potential security concerns.

While mining and processing REE domestically would reduce some reliance on China, Russia, and other "fragile" nations such as the Democratic Republic of Congo, it takes 10 to 15 years or longer before a mine becomes operational and costs many millions of dollars. Another concern for the industrial base is the price for REE from China, and other foreign sources may be significantly lower than the marginal costs incurred by U.S. firms. As a result, the federal government may need to expand DPA authorities or Congress may need to prescribe permanent legislation to better encourage firms to invest in domestic mining.

Appendix III – 2019 U.S. Net Import Reliance[171]

2019 U.S. NET IMPORT RELIANCE[1]

Commodity	Percent	Major import sources (2015–18)[2]
ARSENIC (all forms)	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, Vietnam, South Africa, China
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (natural)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea, Taiwan
MANGANESE	100	South Africa, Gabon, Australia, Georgia
MICA, sheet (natural)	100	China, Brazil, Belgium, Austria
NEPHELINE SYENITE	100	Canada
NIOBIUM (columbium)	100	Brazil, Canada, Russia, Germany
RARE EARTHS[3] (compounds and metal)	100	China, Estonia, Japan, Malaysia
RUBIDIUM	100	Canada
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	Rwanda, Brazil, Australia, Congo (Kinshasa)
YTTRIUM	100	China, Estonia, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
BISMUTH	96	China, Belgium, Mexico, Republic of Korea
TELLURIUM	>95	Canada, China, Germany
VANADIUM	94	Austria, Canada, Russia, Republic of Korea
TITANIUM MINERAL CONCENTRATES	93	South Africa, Australia, Canada, Mozambique
POTASH	91	Canada, Russia, Belarus, Israel
DIAMOND (industrial stones)	88	India, South Africa, Botswana, Australia
BARITE	87	China, India, Morocco, Mexico
ZINC (refined)	87	Canada, Mexico, Australia, Peru
TITANIUM (sponge)	86	Japan, Kazakhstan, Ukraine, China, Russia
ANTIMONY (metal and oxide)	84	China, Thailand, Belgium, India
RHENIUM	82	Chile, Germany, Kazakhstan, Canada
STONE (dimension)	81	China, Brazil, Italy, Turkey
COBALT	78	Norway, Japan, China, Canada
TIN (refined)	77	Indonesia, Malaysia, Peru, Bolivia
ABRASIVES, fused Al oxide (crude)	>75	China, Hong Kong, France, Canada
BAUXITE	>75	Jamaica, Brazil, Guinea, Guyana
CHROMIUM	72	South Africa, Kazakhstan, Russia
PEAT	70	Canada
SILVER	68	Mexico, Canada, Peru, Poland
GARNET (industrial)	64	Australia, India, South Africa, China
PLATINUM	64	South Africa, Germany, Italy, Russia
ALUMINA	54	Brazil, Australia, Jamaica, Canada
MAGNESIUM COMPOUNDS	52	China, Canada, Australia, Hong Kong
ABRASIVES, silicon carbide (crude)	>50	China, South Africa, Netherlands, Hong Kong
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
IRON OXIDE PIGMENTS (natural and synthetic)	>50	China, Germany, Brazil, Canada
TUNGSTEN	>50	China, Bolivia, Germany, Spain
DIAMOND (industrial dust, grit, and powder)	50	China, Ireland, Republic of Korea, Russia
CADMIUM	<50	China, Australia, Canada, Peru
MAGNESIUM METAL	<50	Israel, Canada, Mexico, United Kingdom
NICKEL	47	Canada, Norway, Australia, Finland
SILICON (metal and ferrosilicon)	41	Russia, Brazil, Canada
MICA, scrap and flake (natural)	37	Canada, China, India, Finland
COPPER (refined)	35	Chile, Canada, Mexico
PALLADIUM	32	South Africa, Russia, Germany, Italy
LEAD (refined)	30	Canada, Mexico, Republic of Korea, India
SALT	29	Chile, Canada, Mexico, Egypt
PERLITE	28	Greece, China, Mexico
LITHIUM	>25	Argentina, Chile, China
BROMINE	<25	Israel, Jordan, China
SELENIUM	<25	China, Philippines, Mexico, Germany
ALUMINUM	22	Canada, Russia, United Arab Emirates, China
IRON and STEEL	21	Canada, Brazil, Republic of Korea

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (abrasives, metallic; boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zirconium mineral concentrates) or less than 21% import reliant (beryllium; cement; feldspar; gypsum; iron and steel slag; lime; nitrogen (fixed)–ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; talc and pyrophyllite; and vermiculite.). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]In descending order of import share.

[3]Data include lanthanides.

Appendix IV

FIGURE 3 : CURRENT STATUS OF DLA STOCKPILES			
Critical Minerals	**U.S. Depen-dence %**	**Stockpile Status or Government Action**	**Import Source**
Niobium	100	Current	Russia
Quartz crystals	100	Current	China
Manganese	100	Selling Off	South Africa
Tantalum	100	Current	Brazil, Australia, Canada
Yttrium	100	Current	China
+16, **Total 21**	100	**Not Stockpiled**	
Cobalt	72	Current	China
Germanium	50	Current	China, Russia
Lithium	50	Current	China
Titanium	91	Current	China, South Africa
Tungsten	50	Current	China
+24, **Total 31**		**Not Stockpiled**	
Chromium	69	Selling Off	Russia, South Africa
+3, **Total 9**		**Not Stockpiled**	
Platinum	68	Current	South Africa
+6, **Total 10**		**Not Stockpiled**	
Source: DLA (*National Defense Stockpile*), GoldGeologist.com			

Appendix V

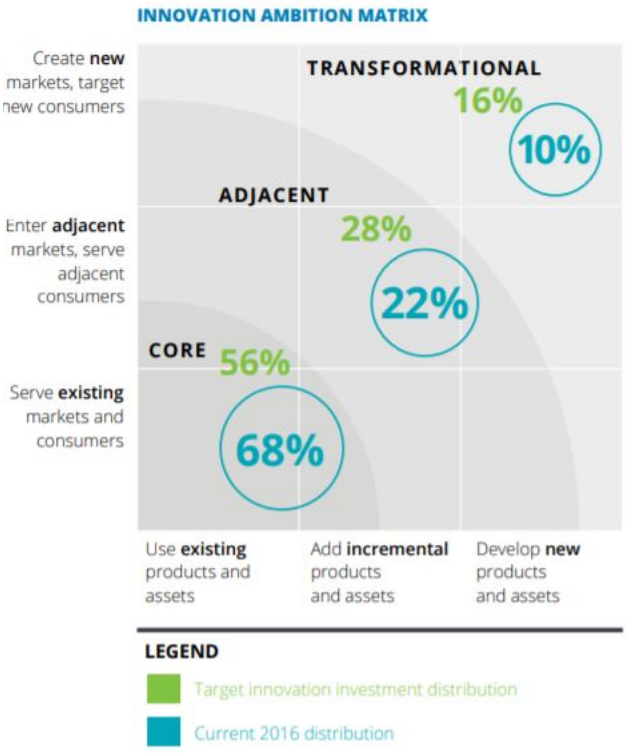
FIGURE 4 : DLA STOCKPILED COMMODITIES OVER TIME		
Time Period	**Number**	**Value $**
Korean War (1952)	75	8.9 billion
Mid 1950s (1956)	-	10.4 billion
Late 1950s (1958)	12	-
1962	-	7.7 billion
1965	-	6.1 billion
1999	40	3.5 billion
2001	33	2.5 billion
2006	22	1.6 billion
2011	14	1.4 billion
2016	18	1.2 billion
Source: DLA (*National Defense Stockpile*), GoldGeologist.com		

Appendix VI – Innovation in Strategic Materials

Innovation Definition

Deloitte's Innovation in Mining series offers a definition of innovation in the mining industry: "innovation [as separate from invention] is the creation of a new [to our market or the world], viable [creating value for both our customers and ourselves] business offering [ideally going beyond products to platforms, business models and customer experiences][172]." In this publication, Deloitte also introduces a model known as the "Innovation Ambition Matrix" to measure where an industry or company falls on the spectrum of levels of innovation.[173] Figure 1 illustrates the distribution of the mining industry on this matrix based on a study which analyzed information gathered from mining companies. The results of this study show that the majority of mining innovation occurs in the core level (68%), with very little true invention or transformational innovation occurring.[174]

Figure 1 Innovation Ambition Matrix[175]

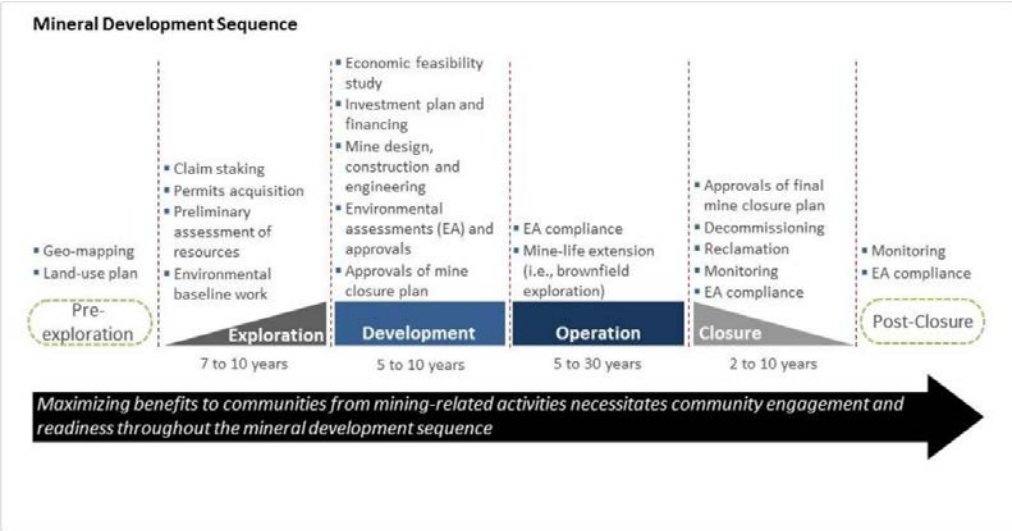


Current State of Operations and Drivers of Innovation

There are several major factors which contribute to understanding why there is such an innovation gap in the mining industry. First, success in the mining industry requires a large initial capital investment balanced against the prospect of long-term profits. Mining companies operate on the margin, optimizing opportunities to streamline existing processes. Another major factor are the time horizons of the mining industry. Per the "Mineral Development Sequence" (Figure 2), after the pre-exploration phase, it takes 15 to 20 years of focused energy and efforts on core

processes for most mines to become operational and generate a profit[176]. Finally, a limiting mindset contributes to lack of innovation initiatives, meaning a "low risk appetite gets in the way."[177]

Figure 2 Mineral Development Sequence[178]



The authors of "Paths for Innovation in the Mining Industry" suggest that, though innovation does exist, adoption of new technology is not largely embraced.[179] Therefore, many industry analysts point to the suppliers of mining equipment as the drivers of any innovation that does occur. The suppliers have the and initiative to continuously create more efficient and effective equipment to maintain or grow their market share. Historically, it has been the suppliers developing the innovative technologies that lower costs and allow mining companies to remain competitive.

Information Technology in Mining and Metals

Information technology (IT) has played a key role in the mining industry of the 21st century. As minerals become scarcer and more difficult to discover and mine, IT is becoming more important in finding and exploiting efficiencies at every stage. In 2015, the mining industry spent about 1% of revenue on IT, lagging most other industries that spend from 5% to 7%.[180] However, the International Data Corporation (IDC) expects IT spending within the mining industry to increase by 50% in 2020.[181] The World Economic Forum (WEF) estimates that digital transformation can save the industry $320 billion through 2025.[182] By fully leveraging these information technologies, mining firms can reverse the trends of declining productivity and allow them make investments in future resources. The key is for the industry to adopt well-proven technologies that have shown promise in other similar industrial uses.

IT in Prospecting and Exploration

GoldSpot Discoveries Corporation reports that there is only a 0.5% chance of success in finding a completely new mineral deposit (greenfield exploration), with the chances increasing to 5% if exploring near a known resource (brownfield exploration), contrasted to the success rate for oil and gas discovery at 88%.[183] Between 2005 and 2014, MinEx Consulting estimated that $140 billion was spent worldwide on exploration only to uncover $93 billion in estimated value of

discoveries, or a dismal 57% value / spend ratio.[184] One of the key limiting factors in this stage is the reliance on human beings to interpret and analyze enormous amounts of data.

Lack of information is not the problem; it may actually be the opposite problem. A single drill sample can create 200 megabytes of data, with a single exploration creating terabytes of data.[185] There is simply too much information for a single person or even teams of people – to accurately and consistently analyze. Machine learning (ML) is a subset of artificial intelligence (AI) that enables computers to "learn" from data and predict results or outcomes. By analyzing historical data, along with other data like output and profitability, ML programs can "learn" to make the connections between seemingly disparate and unrelated data in order to formulate predictions about future discoveries. These predictions could include new places to explore based on surrounding surveyed areas, including greenfield and brownfield sites. The outputs of ML applications are not meant to replace human decision making, but to supplement it (known as augmented intelligence).[186] Intelligent systems will analyze data and predict probable economical locations, but ultimately the decisions must still be validated by humans making judgment calls regarding risk levels.

IT in Mine Operations / Extraction

Operating a mine is expensive and labor intensive. Due to the very high costs of discovering and exploiting new resources, mining companies have focused most of their IT efforts on "sweating existing assets" through autonomous operations at currently operating mines.[187] Autonomous equipment can operate nearly continuously, reducing variation in tasks and also reducing manpower costs.[188] Autonomous haul trucks, blast hole drills, and bulldozers are all able to operate with less cost, more reliability, and greater worker safety than even the most efficient manned operations.[189] Autonomous haul trucks have saved one company 20% over manned costs.[190] McKinsey & Company have estimated costs savings of autonomous haulage as high as 40% depending on the costs of local labor.[191]

Predictive maintenance is another area that can continue to benefit companies. By using predictive analytics, mine operators can discover linkages and relationships between data to develop indicators of impending maintenance issues. Many operators base their maintenance programs on manufacturer's recommended intervals (such as number of miles driven or number of running hours). Successful predictive maintenance programs can quickly result in very real savings for a large fleet. For example, within six months of implementation, a large North American mine was able to achieve 12% savings in its maintenance program while simultaneously increasing availability by 5%.[192] One of the major challenges with optimizing these processes is simply the sheer amount of data available. According to McKinsey & Company, "in 2015, more data are generated every day than existed in total through 2003."[193] Further, some companies use less than 1% of the data already available from their equipment.[194] This presents an enormous potential to harness the available data to identify process bottlenecks and remedy them.

IT in Processing

Much of the technology discussed in mining operations can be applied to processing as well. Processing benefits from automated vehicles, equipment, and process controls much in the same way that mining operations do. Companies have found success is applying advanced analytics to improve processing operations. By identifying second and third order linkages that were previously hidden, one gold mining company was able to improve yield at its leaching plant by "3 to 4 percent within three months."[195] Using advanced modeling techniques, the company

discovered that variations in the dissolved oxygen level were the greatest driver of yield. By making some small tweaks to the oxygen system, the company was able to sustain a $10 to $20 million dollar per year improvement to profit margin.[196]

Government

Though other countries have made significant commitments to stimulate innovation inside the mining community, the U.S. is not keeping pace when it comes to spurring and sponsoring innovation in the mining industry. The U.S. Bureau of Mines (USBM), formed in 1910, played a key role in developing innovative mining technology. However, the recession in the 1980s led to closures of nearly all research and development programs for mining. In the following three decades, there was little to no focus on research and development in the mining community with government sponsorship. The Defense Appropriation Act provided some stimulus towards strategic materials, but specified that it did "not include the authority to encourage the exploration, development, and mining of strategic and critical materials and other materials.[197]" This recently changed when President Donald J. Trump issued Executive Order 13817 in December of 2017, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals.* This order is focused on addressing the vulnerabilities in the strategic materials' supply chain, but it also calls on increasing research and development investments to preserve our leadership in technology innovation[198]. The order listed several goals, including one to "enhance scientific and technical capabilities across critical mineral supply chains" and "increase U.S. private industry investment in innovation and improve technology transfer from federally funded science and technology"[199]. These goals and their supporting objectives and incentives could provide the catalyst for innovation inside the U.S. mining industry, as well as shift the innovation back to the mining companies who have a holistic view of mining operations versus the narrow focus of suppliers.

U.S. National Innovation System

Fortunately, there is a system designed to stimulate innovation, known as the National Innovation System. The U.S. Innovation System is comprised of three elements: the business environment, the regulatory environment, and the innovation policy environment.[200]

When we examine the business environment of the mining system, two subcomponents that drive behavior are time horizons and the risk associated with R&D. This is illustrated by a survey from 2004 of over 400 U.S. executives who overwhelmingly (80%) said they would spend less on R&D and other discretionary spending to meet short-term targets; and more than half stated they would delay new projects even though they would create value in the long-term.[201]

The next element of the National Innovation System is the regulatory environment, in which the U.S. government plays a major role. In some cases, regulations will stimulate innovation through tax, trade, and economic policies. In the mining industry, regulation has thwarted innovation, due to environmental and safety concerns, which are heavily influenced by social and cultural factors. This creates a financial burden and shifts resources away from R&D. Additionally, corporations are spending resources on safety precautions and social factors, such as preserving the environment, that take away from the bottom line, leaving fewer resources for R&D.

The third element is the innovation policy environment. Prior to the USBM closing, there was an agency that was geared towards providing direction, incentive, and policies to encourage innovation. As highlighted above, following the closing of the agency until the passing of President Trump's Executive Order, there has been little to no effort from government to collaborate with

research labs and academic institutes or industry. Again, this is another reason why we are not seeing innovation in this industry.

If the industry is going to thrive, it must discover ways to move into transformational innovation. They cannot succeed by making the same products better and better, rather, they need to develop "breakthroughs and inventing things for markets that don't exist yet[202]". The root of all struggles for innovation comes down to the core of financial risk of shifting from building efficiencies to true innovation. The intensive capital requirements, coupled with long time horizons required to generate profits, creates a risk averse environment focused on safe and incremental efficiencies. Ultimately, injecting fiscal resources into the mining industry solely to be used for innovation would alleviate some of the risk associated with innovation.

Appendix VII – Human Capital as a Source of Competitive Advantage

Over the past decade, the United States (U.S.) has been in a race for high-tech supremacy with China, the leading rival nation in this dimension. However, the U.S. lacks adequate resources in terms of the necessary human capital to secure its lead in this race. While China has adequate high-quality skills that have contributed significantly to its economic growth, the U.S. lacks STEM (science, technology, engineer, and math) qualified skills in the workforce, which limits its invention, research and development, and the profusion of new technologies that are essential to the country's economic growth and progress.[203]

The U.S. Congress recognizes that the expertise of specialists in STEM is necessary for technological inventions. For this reason, it empowers Congress to promote the progress of science and other necessary arts by providing investors with patents. The U.S. government is committed to providing funding to enhance the STEM labor supply and promote research and development. Despite the emphasis placed on developing and maintaining STEM skills, there is still a lack of sufficient STEM skills in the American workforce. Not only does the lack of adequate STEM in America's workforce negatively impact its economy, but it also impacts the country's national security negatively. The U.S. military depends on advancements in science and engineering to prevail in current and future conflicts, in particular, in minimizing casualties and in fulfilling other humanitarian missions.

The discussion that follows critically analyzes the concerns of the relevant stakeholders with regard to the shortage of STEM skills in the workforce and its impacts on the national security of the U.S. In recent years, there has been a shortage of workers and candidates to fill positions related to STEM in nearly every industry in the U.S., negatively impacting the country's competitiveness in science and technology. Among the reasons behind this acute shortage is the stagnant and low performance of students in math and sciences and the underrepresentation of women in STEM fields.

According to researcher J.V. Winters, the shortage of STEM qualified skills begins with America's education system. In his assessment, only a few American students in the fourth grade are proficient in math and science and, even by the time they get to the eighth grade, students have not yet gained the right degree of proficiency in these fields. In the eighth grade, a student has to decide to either pursue a career related to STEM fields or not.[204] On average, from this point on, the student will take eight years to graduate with a bachelor's degree in his STEM field of choice and another four years to attain his PhD. Most students view pursuing a career in the STEM fields as too much hassle, taking up too much of their time that they could invest in building a much less demanding career.

The early age of career selection and specialization in the U.S. education system is not only a challenge for the students, but also a concern to stakeholders in companies and government organizations. It presents a challenge in predicting future technological changes. Hence, the stakeholders are not able to predict future demand for specialized STEM personnel to support the national security needs of the country.

STEM is crucial in maintaining a nation's strong economy and protecting its national security, making it extremely important that the U.S. has a productive and high-quality STEM workforce. The U.S. youth is less interested, however, in pursuing careers in the STEM fields compared to youth in other countries such as China and the European region. As a result, the U.S. has, on many occasions, been forced to bring in foreign nationals to work in its research universities and provide them with incentives to remain and continue to contribute to the country's well-being. Currently, non-U.S. citizens attain more than half of the engineering PhDs received

in the U.S. each year. Among PhD graduates, 38% leave the U.S. within five years of their graduation, leaving the country with a shortage of this essential skill.[205]

Employers in the U.S. have reported an acute shortage of STEM workers. This requires U.S. employers to employ STEM professionals overseas despite the high cases of unemployment in the country. Some employers, including the late Steve Jobs, reported hiring STEM personnel from countries like China because there were high numbers of qualified potential candidates from which to choose to fill vacant engineering positions, unlike in the U.S.[206] The U.S. Department of Defense (DoD) recognizes that the main problem the country faces in STEM skills application is not unemployment; instead, it is the knowledge gap that is still present among the potential STEM workforce. In fields such as intelligence and cybersecurity, the DoD predicts an acute shortage of the necessary STEM workforce. The aerospace and defense industry lacks enough aerospace and mechanical engineering staff and potential candidates to fill vacant positions in these areas. The uncertainty of the future and the rapidly advancing technology in STEM is predicted to cause a further shortage of STEM workers in the evolving fields in the near future.

The lack of STEM skills in the U.S. presents a challenge for the nation's entire workforce in the technology-driven economy. STEM is a crucial component of the country's national security and underlines the critical shortages of these skills in the U.S. The current STEM employees in the defense and aerospace industry are mainly aerospace engineers. The overall shortage of engineers and scientists in the U.S. is expected to get more severe as a result of globalization, consequently, affecting U.S. national economic security negatively.

Currently, it is easy for commercial firms to get the STEM workforce they need from abroad, especially with the vast STEM education taking place abroad and particularly in developing countries that produce relatively highly qualified potential STEM professionals. Globalization opens up doors for local firms to move abroad and bring with them the prototype shops that innovate, design, and implement new concepts, production lines, and maintenance facilities. With most of the future consumers of these companies being from developing countries, the companies will be more incentivized to take their manufacturing and engineering business activities to these developing countries, thus affecting the country's economy negatively and increasing the rate of unemployment.

Because the DoD cannot move their activities abroad like the commercial firms, however, they will continue to suffer the shortage of STEM workers. The high rates of unemployment will discourage more people from pursuing STEM-related careers, and this will affect non-commercial aerospace and defense industry's activities negatively in the long-term. STEM's skills and knowledge need to be continuously developed so that they can meet the needs of future technological development and innovations. This department will face challenges in filling STEM ranks with the best quality skills, especially with the notion that working for the government is less fulfilling than working for commercial firms. The few U.S.' PhD graduates seek employment in the commercial industries that also need STEM skills.[207] Most of DoD STEM jobs require U.S. citizenship, but with time, as the shortage in STEM skills continues, the DoD's required to take measures like defining which jobs are most sensitive and require U.S. citizenship than others and utilize talent from abroad for the less sensitive STEM jobs.[208] Doing this has potential adverse effects on national defense security in the long term.

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- **Title IV**: Price and Wage Stabilization (authority to ration consumer goods, to solicit voluntary labor/industry cooperation on wage and price stability, and to fix wage and price ceilings, terminated in 1953).
- **Title V**: Settlement of Labor Disputes (authority to force settlement of labor disputes affecting national defense, terminated in 1953).
- **Title VI**: Control of Consumer and Real Estate Credit (authority to exercise consumer credit controls, to regulate real estate construction credit and loans, and to establish down-payment requirements on veterans' homes, terminated in 1953).
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RioTinto

ES6204 INDUSTRY ANALYSIS – SEMINAR 9

FIRM BRIEF

STEVE GUTIERREZ
BETHANY PETROFSKY
BRETT MEDLIN
LES THOMPSON

FIRM BRIEF AGENDA

RioTinto

- Firm Profile
  - Intro & History
  - Scope & Markets
  - Corporate Strategy & Operations
  - Innovation
- Structure of Industry
  - Porter's Five Forces – Aluminum Market
- Analysis of the Strategy
  - Comparative Advantage – Enterprise / Aluminum
  - Strategic Position – Scope Choice
  - Value Proposition Through the "Four Ps"
  - Activity Map - Key Financial Indicators
- National Security Implications
  - Ability to Meet US National Security
  - Great Power Competition
  - Defense Readiness, Surge & Mobilization
  - Policy Recommendations
- Questions?

RIO TINTO HISTORY

RioTinto

1873 — Expands Spanish copper business into Northern Rhodesia

1925 — Exploration in Africa, Australia (AU), & Canada.. Uranium & Bauxite mining activities.

1950s — AU iron ore business founded. UK & AU entities merge. Business w/Japan. Acquires U.S. Borax.

1960s — AU Argyle diamond mine discovered

1970s — Acquires Cu assets in Chile and U.S. Global leader in Iron & titanium dioxide feedstock.

1980s — Recognizes environmental considerations. Applies carbon pricing.

1990s — Founding member of ICCM; safe, fair and sustainable mining and metals industry. Cu mining in Mongolia. & Arizona. Diamonds in Canada,

2000s — A decade and the beginning of an era of sustainable mining business initiatives.

2010s

2020

FOUNDING | INTERNATIONALIZATION | SUSTAINABLE MINING

Gutierrez

RIO TINTO SCOPE

RioTinto

Value Chain:

- Company Dual-Listed on London Stock Exchange: Rio Tinto PLC (RIO) & Australian Securities Exchange: Rio Tinto Limited (RIO)
- British Branch Traded on NYSE
- Operating in 36 countries / 6 Continents
- 60 Operations (Mines, Port Terminals, R&D Facilities, etc.)
- 46,000 employees
- 2,000 customers across 96 countries
- 200 contracted ships managed at any one time
- 37,000 suppliers in 120 locations

MINING[DOT]COM TOP 50

	Company	Headquarters	Operations	Market Cap	1Y Change %
1.	BHP Group	Melbourne	Diversified	137.5B	13.7
2.	Rio Tinto	Melbourne	Diversified	114.4B	28.0
3.	Vale	Rio de Janeiro	Iron ore, Nickel	63.6B	2.0
4.	Norilsk Nickel	Moscow	Nickel, PGM	49.0B	47.0
5.	Glencore	Baar	Diversified	42.5B	-19.2
6.	Anglo American	London	Diversified	40.3B	24.3
7.	Newmont Goldcorp	Denver	Gold	35.6B	25.4
8.	Southern Copper	Phoenix	Copper	32.8B	38.1
9.	Barrick Gold	Toronto	Gold	32.5B	30.9
10.	Nutrien	Saskatoon	Potash	27.4B	-3.0

RIO TINTO MARKETS

RioTinto

Aluminium

$10.3B Gross Revenue; $2.3B Underlying EBITDA; 55.1MT Bauxite Produced; 3,171KT Produced

- Industry-leading bauxite position
- Alumina refineries provide competitive security of supply for our smelters
- Sector-leading primary aluminium metal EBITDA margins, driven by low-carbon, low-cost power

Copper & Diamonds

- Significant producer of copper from our assets in the USA, Mongolia and Chile
- Diverse diamonds business
- Maximises our technical underground mining expertise

$5.8B Gross Revenue; $2.1B Underlying EBITDA 577KT Mined Copper; 17,030K Carats Diamonds

Energy & Minerals

$5.2B Gross Revenue; $1.8B Underlying EBITDA; 1,206KT Titanium Dioxide Slag

- Leading supplier of titanium dioxide feedstocks, zircon and borates
- Supplier of uranium
- Iron Ore Company of Canada produces concentrates and pellets

520KT Borates 10.5MT Iron Ore Pellets & Concentrate

Iron Ore

$24.1B Gross Revenue; $16.1B Underlying EBITDA; 326.7MT Produced (100% Basis)

- World-class Pilbara operations in Western Australia
- Supplies our premium Pilbara Blend lump and fines products
- Industry-leading margins supported by automation, innovation and technology

Gutierrez

WHY THESE MARKETS?

COMPETITIVE ADVANTAGE

RioTinto

Iron Ore
World leader

Copper
Well-timed growth

Aluminium
World leader

Minerals & Ventures
Products for the future

Exploration
World leading

Urbanisation | Electrification | Transition to the low-carbon economy

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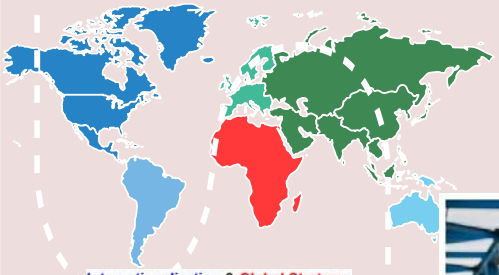
RIO TINTO STRATEGY

RioTinto



"Our strategy is to create superior value for shareholders by meeting our customers' needs, maximizing cash from our world-class assets and allocating capital with discipline. We do this by focusing on the 'four Ps': Portfolio, People, Partners and Performance."

Doesn't Do: Volume over Value; Fossil Fuels

Portfolio | Performance | People | Partners

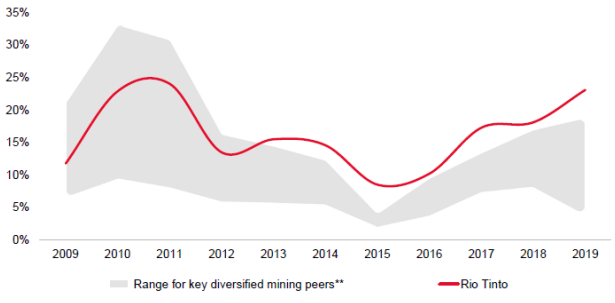
Gutierrez

IS IT WORKING?

RioTinto

Maintained industry-leading profitability….

Return on invested capital*, post tax



Average ROCE 2009 to 2019 of 16%

Average ROCE 2001 to 2008 of 22%

Only one year of single digit ROCE in two decades

Source: CSFB and company information.
*Return on invested Capital is defined as tax adjusted EBIT / (consolidated book equity + net debt). ** Average of peers comprising Anglo American, BHP, Glencore and Vale

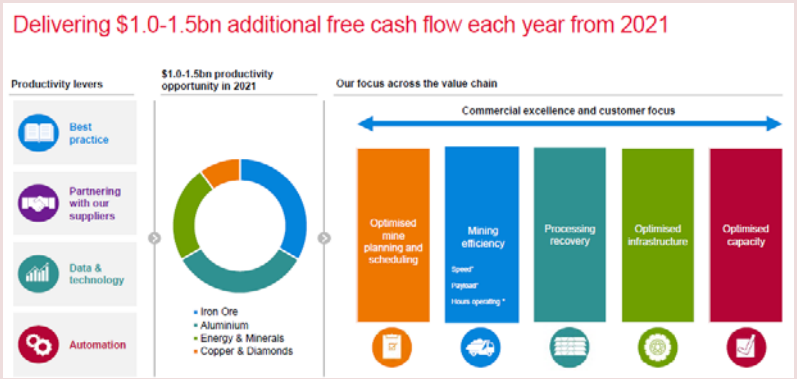
Gutierrez

RIO TINTO OPS
INTERNATIONALIZATION & ACTIVITY LOCATION

Gutierrez

INNOVATION
EXPLOITATIVE BUSINESS

	Exploitative Business
Strategic intent	cost, profit
Critical tasks	operations, efficiency, incremental innovation
Competencies	operational
Structure	formal, mechanistic
Controls, rewards	margins, productivity
Culture	efficiency, low risk, quality, customers
Leadership role	authoritative, top-down



**3 New Centers of Excellence – Processing in Montreal, Surface Mining in Perth and Underground Mining in Brisbane*

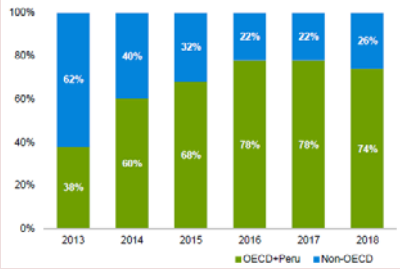
Gutierrez

INNOVATION
EXPLORATORY BUSINESS

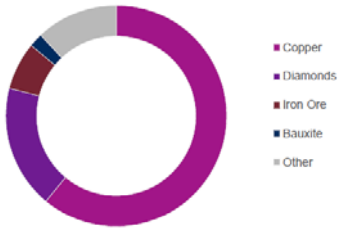
RioTinto

	Exploratory Business
Strategic intent	innovation, growth
Critical tasks	adaptability, new products, breakthrough innovation
Competencies	entrepreneurial
Structure	adaptive loose
Controls, rewards	milestones, growth
Culture	risk taking, speed, flexibility, experimentation
Leadership role	visionary, bold

Exploring across 18 different countries
Expenditure by region, 2013 to 2018



$231 million spent on greenfield exploration in 2018
Expenditure by commodity



*7 different commodities being explored in 17 countries (2019)

INNOVATION
TIMELINE

RioTinto

Gutierrez

Porter's Five Forces Model

Rio Tinto Market's Analytic Boundaries

Medlin

Porter's Five Forces Model

Rio Tinto Market's Analytic Boundaries

NEW ENTRY

NEW ENTRANTS
-Barriers to Entry
-Time and Cost of Entry
-Economies of Scale
-Cost Advantages
-Technology Protection

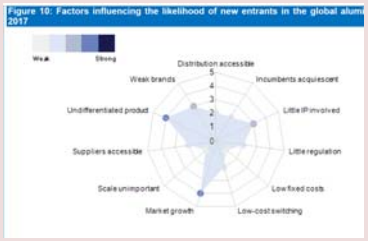
ASSESSED AS WEAK

Relevant Drivers (Across the I[5])

§ Large multinational companies that are vertically integrated
§ Process requires access to bauxite
▪ Intense Capital Investment / High Fixed Costs
▪ Price Fluctuations
▪ Expanding Difficult
▪ China

Rio Tinto Strategy

▪ Economy of scale advantage
▪ Focus on innovation to differentiate its products
▪ Marketing



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Porter's Five Forces Model

Rio Tinto Market's Analytic Boundaries

BUYERS

POWER OF BUYERS

-# and Size of Customer
-Size of Each Customer Order
-Differences Between Competitors
-Price Sensitivity
-Buyers Ability to Substitute
-Buyers Information Availability
-Switching Cost

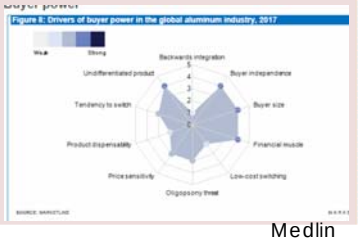
ASSESSED AS MODERATE

Relevant Drivers (Across the I[5])

§ Large Companies w/Financial Muscle
§ Aviation, Automotive, Construction, Packaging
§ Seek to Negotiate Long-Term Contracts at Fixed Rates
§ Undifferentiated Product
§ Competitors are Attractive
§ Easy to Pass Costs to Consumers
§ High Switching Costs

Rio Tinto Strategy

- Focus on Innovation and differentiation
- Marketing aims to build brand loyalty
- Focus on low-income buyers



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Porter's Five Forces Model

Rio Tinto Market's Analytic Boundaries

SUBSTITUTES

THREAT FROM SUBSTITUTIONS

-Substitute Performance
-Cost of Change

ASSESSED AS WEAK

Relevant Drivers (Across the I[5])

§ Lightweight, strong, and cost-effective
§ Threat of substitution in packaging, transportation, and structural support
§ Requires production processes changes and additional research
§ Price subject to fluctuation
§ Suppliers provide substitutions as well

Rio Tinto Strategy

- Higher quality product
- Differentiating products
- Market research to meet customers needs

Medlin

Porter's Five Forces Model

Rio Tinto Market's Analytic Boundaries

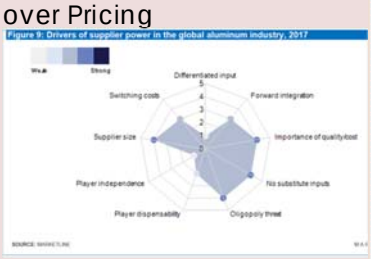
SUPPLIERS

POWER OF SUPPLIERS
-# of Suppliers
-Size of Suppliers
-Uniqueness of Product
-Ability to Substitute
-Cost of Change

ASSESSED AS MODERATE

Relevant Drivers (Across the I[5])

- Raw Materials Suppliers Have Less Control Over Prices
- Product by Suppliers is Standardized with Low-Switching Costs
- Low Substitutions
- Low Threat for Forward Integration
- Pricing Closely Tied to that of Suppliers
- Electricity Suppliers have More Control over Pricing



Rio Tinto Strategy

- Purchase Raw Materials at Low Cost from Supplies
  - -- Switching Costs are Low
  - -- Multiple Suppliers w/in Supply Chain
- Enter Long-Term Contracts with Energy Suppliers

Medlin

Porter's Five Forces Model

Rio Tinto Market's Analytic Boundaries

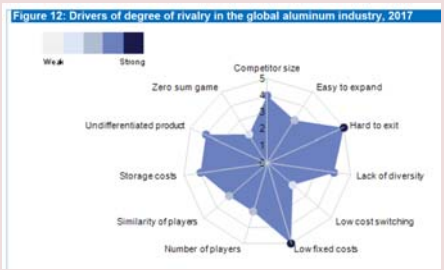
COMPETITIVE RIVALRY

COMPETITIVE RIVALRY
-# of Competitors
-Cost of Leaving Market
-Quality Differences
-Other Differences

ASSESSED AS STRONG

Relevant Drivers (Across the I[5])

- High Concentration Ratio – Multinational Companies Dominate
- Intense Capital Investment / High Fixed Costs
- Location, location, location…
- Energy Intensive Ops
- Expanding Difficult
- Little Differentiation



Rio Tinto Strategy

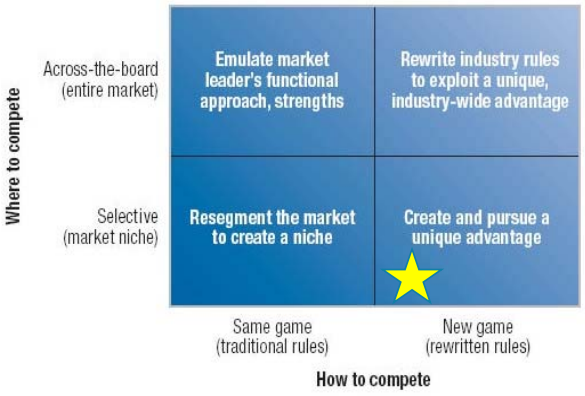
- Vertical Integration
- Focus on Asia (71% Market)
- Differentiate (ASI Certified)
- Diversification
- Invest in R&D

Medlin

Comparative Advantages

RioTinto

- **Size, Scope, & International Reach**
  - Vertical Integration
  - Leading supplier of titanium dioxide feedstocks, zircon and borates
- **High Quality Mines**
  - Tier 1 Copper Mine (Oyu Tolgoi – Mongolia)
  - Kennecott Mine (Higher Grade)
- **High End products – "Value over Volume"**
  - Pilbara Blend Iron Ore
  - Gem Quality Diamonds - Diavik Diamond Mine
    - 1st Mining company - certified by Responsible Jewlery Council
- **Significant Investment in Exploration, Innovation & Technology**
  - Discovered new mineral - Jaderite
  - AutoHaul Train, fully integrated mine operation and simulation systems (Koodaideri)
- **Corporate Responsibility & Sustainability**
  - 2.4mt reduction in greenhouse gas emissions



Source: Rio Tinto 2018 Annual Report and Rio Tinto Chart Book (2019)

Petrofsky

Strategic Position: Scope Choice

RioTinto

What Rio Tinto does not do:

- Fossil Fuel Production (only major mining company to do so)
  - Sold Hail Creek and Kestrel mines; sold Valeria and Winchester South coal development projects
- Specialize in only one market or low-end product offerings
- Manage and control all operations and joint ventures (this does open them up to risk)
- Overlook local communities and suppliers

"The preference is to buy local products and engage local services. In 2018, we spent $12.3 billion with more than 37,000 suppliers in more than 120 locations. In areas where the skills, goods and standards we need are not available, we invest in developing that capacity, and in turn, to establish and support local economic development. "

Source: https://www.riotinto.com/footer/suppliers

Petrofsky

Comparative Advantages - Aluminum

RioTinto

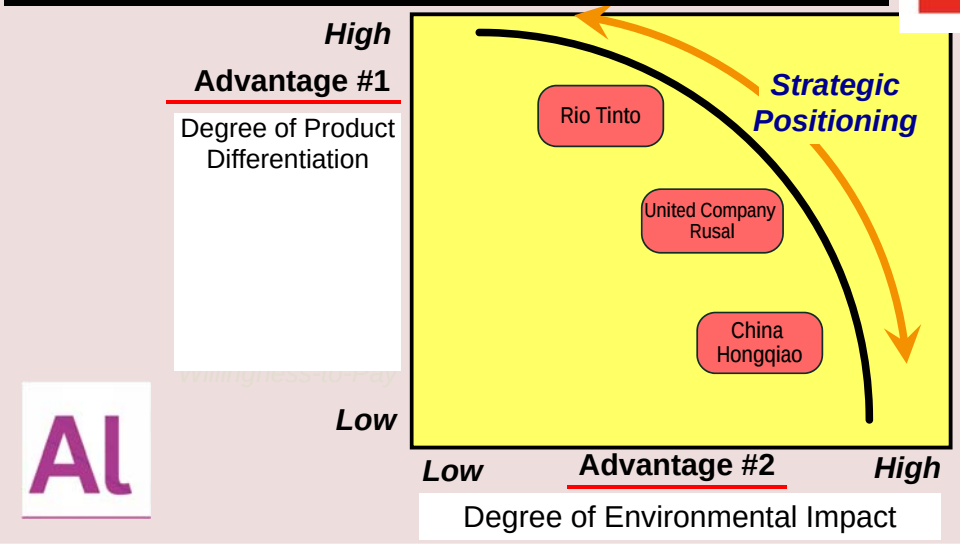
- 2nd largest bauxite producer in the world
  - Size, quality, proximity to markets
  - Amrun Bauxite MIne
- Canadian Operations
  - Low first-quartile cost curve
  - Low-carbon, low-cost hydropower
- 1st Producer to have metal certified "responsible" by the Aluminum Stewardship Initiative (ASI)
- Value added product (VAP) enhances margins
  - VAP 54% of portfolio, targeting >63%
  - New wheel alloy called Revolution-Al™
    - low CO2 aluminum

Source: Rio Tinto 2018 Annual Report and Rio Tinto Chart Book (2019)

Petrofsky

Strategic Position: Advantage

RioTinto



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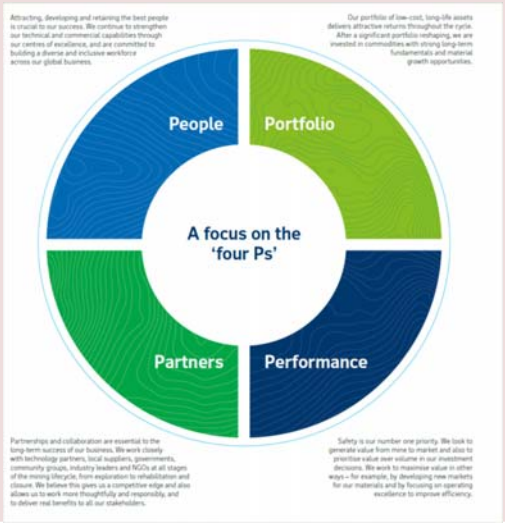
Value Proposition Through the "Four Ps"

RioTinto

Consistent Reinforcing Activity System



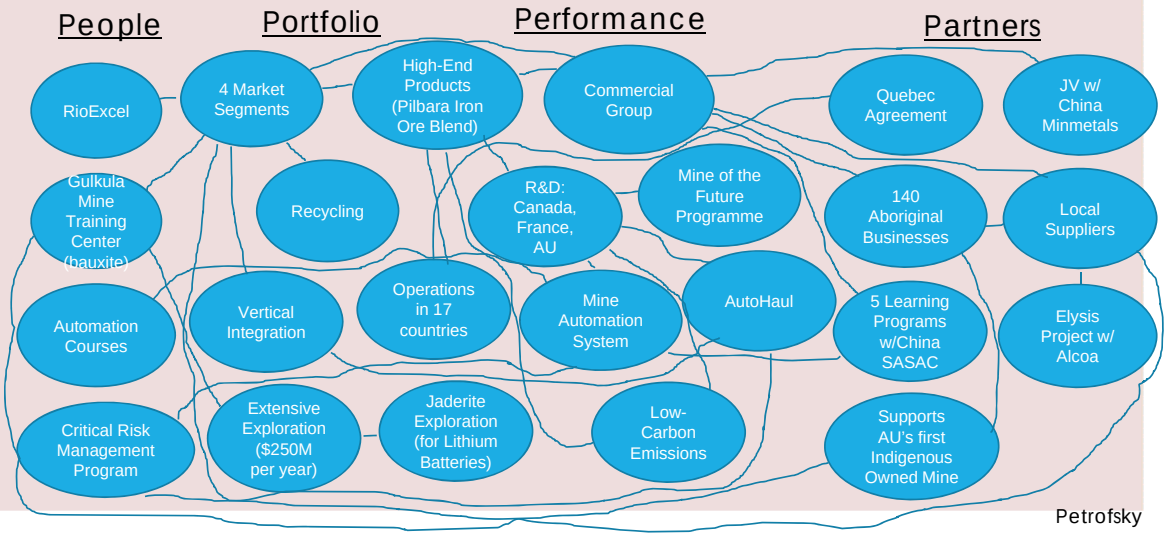
Aligns to Strategy: Meet Customer Needs, Maximize Cash, Allocate Capital w/Discipline

Source: Rio Tinto 2018 Annual Report, pg. 16.

Petrofsky

Activity System Map

RioTinto



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Key Performance Indicators

RioTinto

Source: Rio Tinto 2018 Annual Report, pgs. 3 and 19

Petrofsky

Key Financial Indicators

RioTinto

Measure	Value	China Hongqiao Group	United Company RUSAL	Interpretation
Profitability Ratios				
Sales Growth	1.2%	-7.9%	3.1%	Issues w/U.S. tariffs, alumina supply disruptions, steel demand in China
Return on Assets (ROA)	14.6%	3.2%	10.8%	Outstanding! (average ROEs in the mining industry are between 5-9%)
Return on Invested Capital (ROIC)	17.8%	4.5%	12.6%	Excellent; ROIC > WACC = value because firm is investing in profitable projects/capital expenditures
Return on Equity (ROE)	31.2%	9%	32.6%	Excellent generation of profits from shareholders' investments
Profit Margin	33.7%	6%	16.5%	Outstanding! Due to vertical integration (hydropower) and assets positioned in the lower part of the industry cost curve
Weighted Average Cost of Capital (WACC)	9%	7%	7.5%	Must pay a slightly higher rate of return to investors than its competitors

Source: MarketLine Financials – all numbers are from 2018 WACC Source: https://finbox.com/NYSE:ACH/explorer/wacc

Petrofsky

Key Financial Indicators

RioTinto

Measure	Value	China Hongqiao Group	United Company RUSAL	Interpretation
Solvency and Leverage Ratios				
Current Ratio	1.9	1.6	2.2	Current Ratio >1, so it is fairly liquid; does have extra cash that could be reinvested
Debt to Equity Ratio	0.3	1.3	1.6	Liabilities only represent 30% of stockholder's equity (most likely due to the large retirement of debt); Hongqiao and RUSAL are more in the normal range (1.5)
Market Related Ratios				
Earnings Per Share (EPS)	7.9	0.6	0.1	By far the most profitable of all it's competitors

Source: MarketLine Financials – all numbers are from 2018

Petrofsky

NATIONAL SECURITY IMPLICATIONS

RioTinto

Rio Tinto's Ability to Meet US National Security

- *Two of the US 35 critical minerals:* ***Aluminum and Titanium***

Rio Tinto's Global Trade Portfolio

- *China (45%)*
- *US (15%)*
- *Asia (12%)*
- *Japan (10%)*
- *Europe (9%)*
- *Canada (3%)*
- *Australia (2%)*

Thompson

NATIONAL SECURITY IMPLICATIONS

RioTinto

Industrial Security

- *Well Diversified in Operations and Product Offerings*
- *Not Vulnerable in any Specific Portion of its Supply Chain*
- *Invested Heavily in Safety and Information Technology Programs (Including Cyber Security)*

Supply Chain Management

- *Rio Tinto Maintains Firm Control Over Its Supply Chain*
- *It Maintains Global Operations in 36 Countries*

Thompson

NATIONAL SECURITY IMPLICATIONS

RioTinto

Great Power Competition

- *Rio Tinto Relies on China for 45% of Sales*
- *Pushback Against Chinese Acquisitions*
- *Chinese State-Owned Companies Increasingly Buying Shares of Rio Tinto Stock*
- *Chinese Strategy for the Last Few Decades*

Thompson

NATIONAL SECURITY IMPLICATIONS

RioTinto

Defense Readiness, Surge & Mobilization

- *More Capacity*
- *Incentive to Move into Finished Products*

Policies to Improve Firm Abilities

- *Reduce or Eliminate Burdensome Regulations*
- *Environment*
- *National Defense Policy*
- *Trade Policy*
- *Critical Material Cooperatives*

Thompson

SUMMARY

RioTinto

Rio Tinto

- Perform Today - Profit / Transform for Tomorrow – Innovation & Exploration
- Diversifies Across Markets & Customers
  - Emphasize Sustainability
- Capitalize Comparative Advantages to Offset Market Forces
  - "Value over Volume"
- Enable Value Creation: "4 Ps"
- Maximize Cash Flow
  - Shareholder Returns & Strategic Capital Allocation
- US National Security: Policies to Incentive Surge Production Capabilities

Gutierrez, Petrofsky, Thompson

NATIONAL DEFENSE UNIVERSITY

Freeport McMoRan Inc

Structure • Conduct • Performance • Policy

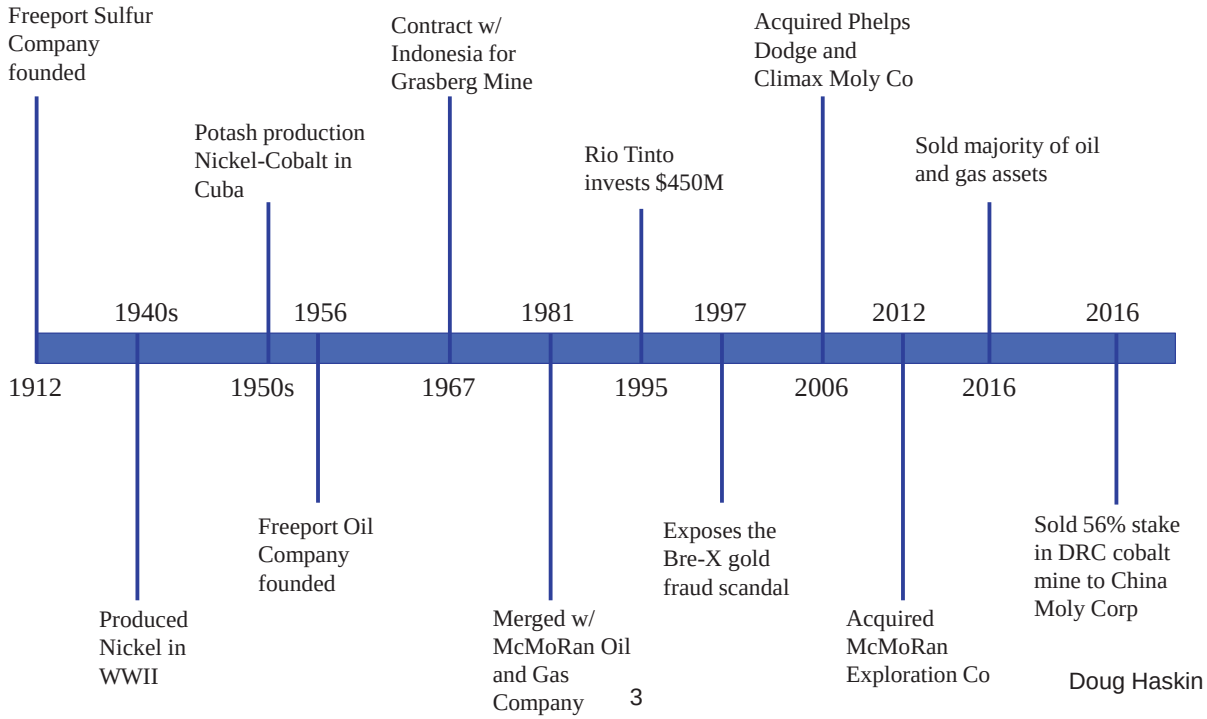
Lance Giannone
Doug Haskin
Michelle Quitugua
André Schlappe

Industry Analysis

Introduction

- Freeport McMoRan is the largest public US mining company and 9th largest in the world
- After years of diversifying, Freeport has re-focused on copper and its co / by-products (gold, molybdenum)
- Freeport runs the Grasberg copper and gold mine
  - Biggest asset
  - Biggest liability?
- Future looks good, but long term viability of Grasberg is questionable

Freeport McMoRan History



Doug Haskin

About Freeport McMoRan

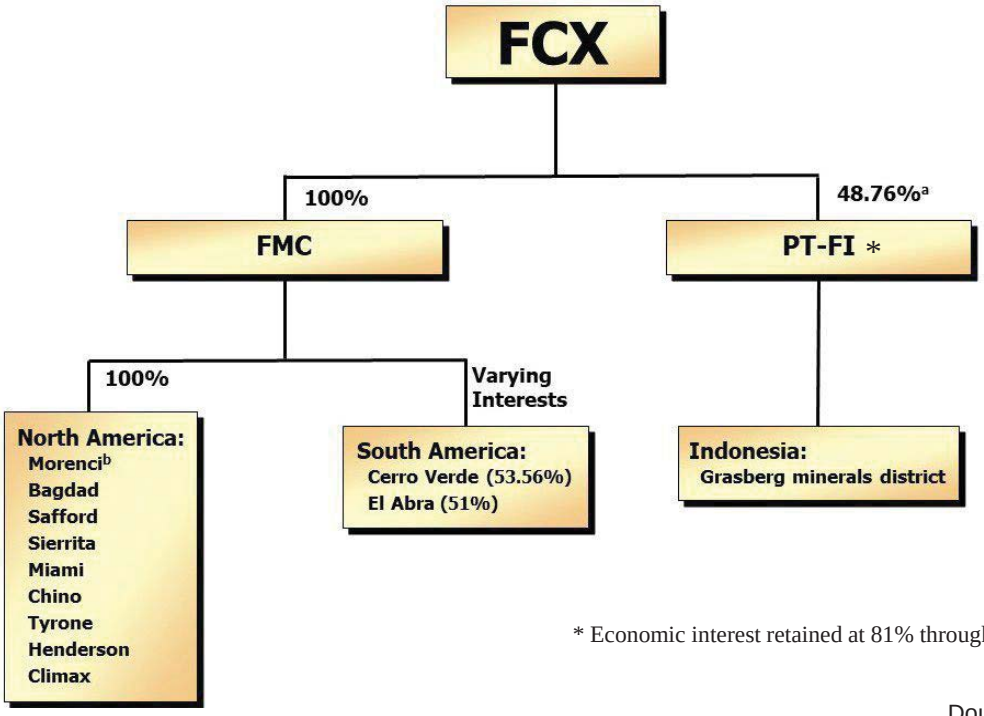
- HQs in Phoenix, AZ
- Copper (4th), gold (6th), and molybdenum (1st)
- NYSE ticker: FCX
- Ranked #170 in 2019 Fortune 500
- 27,500 company employees; 40,600 contractors
- Market Cap: $10.9 billion

	2019	2018	2017
Revenue	$14,402 M	$18,628 M	$16,403 M
Net (loss) income	($239 M)	$2,602 M	$1,817 M

- $4.2 billion revenue drop due to completion of open pit mining at Grasberg mine and two year transition to underground block cave

Doug Haskin

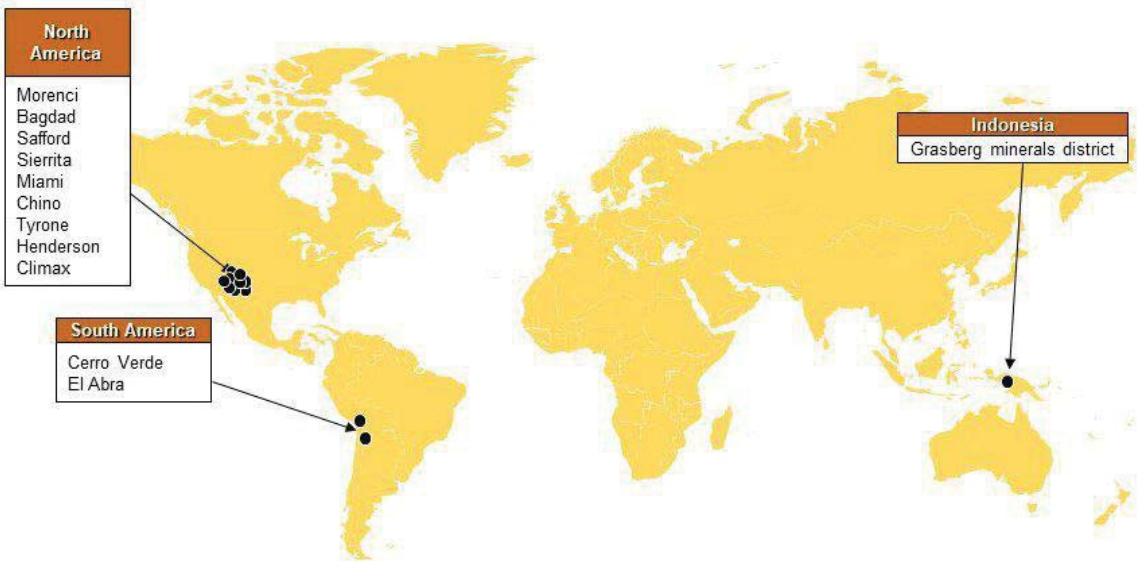
Freeport McMoRan Structure



* Economic interest retained at 81% through 2022

Doug Haskin

A Global Mining Company



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Grasberg Mine and PT Smelting

Grasberg Mine

- World's largest gold mine
- Second largest copper mine
- Indonesia's biggest taxpayer
- Previously a JV with Rio Tinto; Rio sold share to Indonesia in 2018

Firm Profile: Them vs. Us

- 2018 Annual Report Strategy: "…[F]ocus on maximizing the value of our existing resource base through cost management, productivity and technology, executing our plan to successfully transition from open-pit mining to large-scale underground mining at Grasberg, generating cash flows to enhance shareholder returns and creating value organically from our large, undeveloped resource position."[1]

- Team FCX Translation: Instead of going wide, FCX is going deep.
  - FCX "redesigned the whole business logic around a simplified product line sold through a limited set of outlets," focusing on the **long-term** by **reinvesting** in the firm vice the short-term with paid dividends.
  - Simplified product line = **Copper** and **two by-products**
  - Limited set of outlets = N. America, S. America, Indonesia

Firm Profile cont.

- Business segments
  - Copper: Primary segment (79% of revenue in 2019)
  - Gold: By-product/Co-product of copper (11% of revenue in 2019)
  - Molybdenum: By-product/Co-product of copper (8% of revenue in 2019)

- Divisions of mining operations
  - North America copper mines: Arizona, Colorado, New Mexico
  - South America mining: Chile and Peru
  - Indonesia mining: Grasburg Minerals District
  - Molybdenum mines: Arizona, Colorado, Peru,
  - Other operating segments: Atlantic copper smelter/refinery (Spain); PT Smelting (Indonesia); Miami smelter (Arizona); Rod & Refining operations (Arizona, Connecticut, Texas, New Jersey); Molybdenum conversion facilities (Arizona, Iowa, the Netherlands, United Kingdom); Non-operating copper mines; *Freeport Cobalt*

Doug Haskin

Competitive Spectrum

- Market Analysis
  - **BLUF: Copper, Gold, Molybdenum = Competitive Markets**
    - Market participants: **MANY** buyers and sellers
    - Product differentiation: Some differentiation by grade of ore but products are **NOT** unique
    - Information: **SIGNIFICANT** price information available from commodities markets
    - Entry/Exit barriers: **HIGH** entry and exit barriers

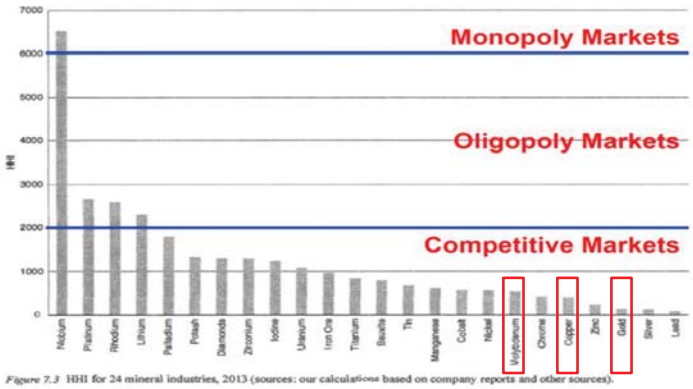


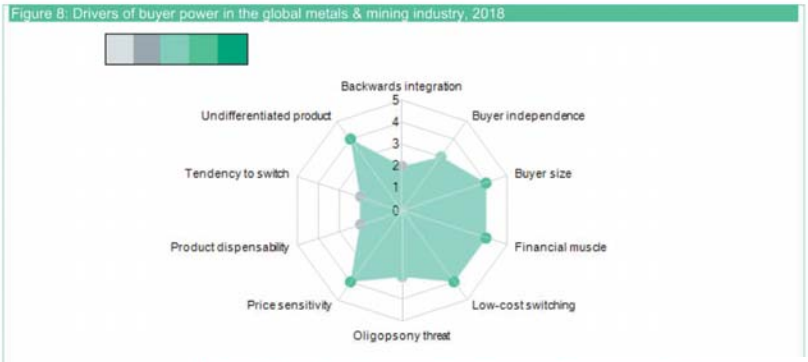
Figure 7.3 HHI for 24 mineral industries, 2013 (sources: our calculations based on company reports and other sources).

Michelle Quitugua

Industry Analysis cont: Five Forces

Industry Analysis cont: Five Forces

Buyer Power



Supplier Power

Industry Analysis cont: Five Forces

Bargaining Power of Buyers

- Moderate (Direct/Downstream buyers)
  - Increased b/c individual producers cannot "control the global market" & may not wish to behave as an oligopoly (Cu/Mo)
  - Negotiating power of Indonesian government over Grasberg Mineral District, which is a designated Indonesian national asset
  - Increased by influence of Chinese demand (Cu)
  - Increased by little product differentiation (Cu/Mo/Au)
  - Increased by availability of substitutes (Mo/Cu), stockpiles (Cu), and recycling options (Mo)
  - Increased by availability of price information from commodities markets (Cu/Au/Mo)
  - Mitigated by inability to backward integrate (Cu/Au/Mo)

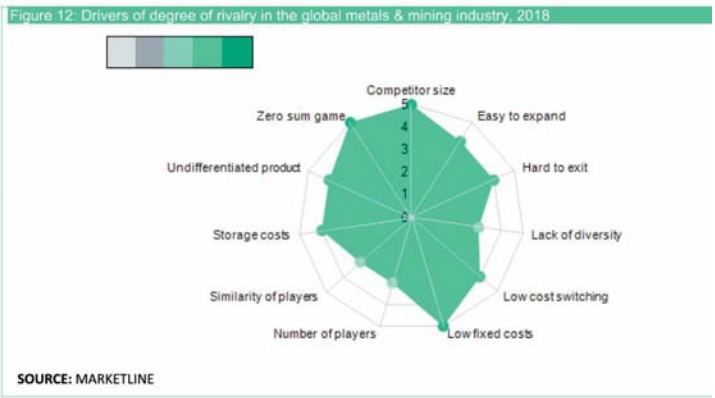
Bargaining Power of Suppliers

- Moderate
  - Increased by high labor costs in U.S. (Cu/Au/Mo)
  - Increased by influence of unions in international labor markets (Cu)
  - Increased by fluctuating logistics expenses (e.g., transportation costs, processing chemicals, water, electricity, etc.) (Cu/Au/Mo)
  - Increased by pending litigation over water and other resources (Cu/Mo)
  - Mitigated by inability to forward integrate (Cu/Au/Mo)
  - Mitigated by producers' vertical integration (Cu/Mo)

Industry Analysis cont: Five Forces

Threat of New Entrants

Degree of Rivalry



Industry Analysis cont: Five Forces

Rivalry among Competitors

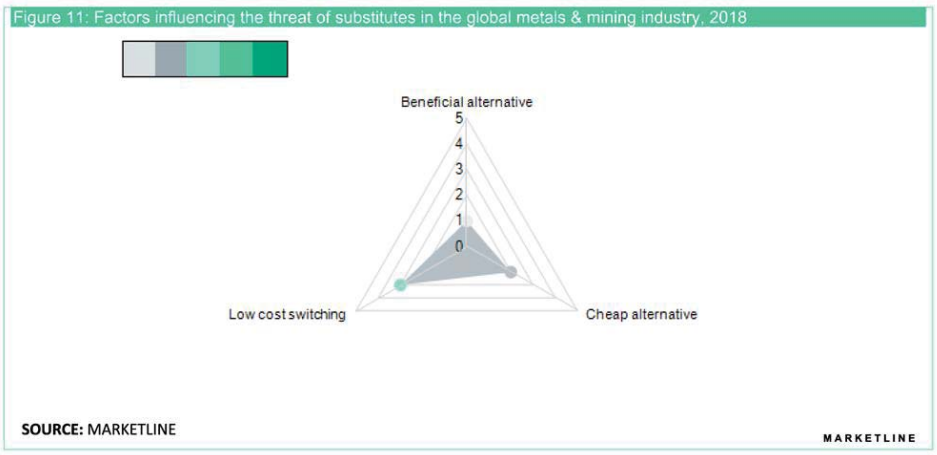
- High
  - Increased because the industries are concentrated
  - Increased by high exit barriers
  - Increased by significant input costs that are outside of the producers' control (e.g., currency fluctuations)
  - Increased by little product differentiation
  - Increased because buyers are well informed by commodities markets
  - Increased by zero sum vice positive sum game
  - Note: Above items apply to all of FCX's business segments.

Threat of New Entry

- Low
  - Decreased by high entry barriers and substantial capital requirements
  - Decreased by geologic limitations
  - Decreased by significant government policies / regulations
  - Note: Above items apply to all of FCX's business segments.

Industry Analysis cont: Five Forces

Threat of Substitutes



Industry Analysis cont: Five Forces

Threat of Substitution

- Moderate
  - Increased by impact of stockpiles (Cu)
  - Increased by other materials with similar properties (Mo)
  - Increased by supply provided by recycling (Mo)
  - Mitigated by lack of substitutes for gold

Complements or Other Factor

- Low
  - Mitigated by gold's importance as bullion, independent of its beneficial chemical properties
  - Mitigated by the *multiple* uses of copper so that no single complement significantly influences copper prices (e.g., construction, electronic product manufacturers, metal manufacturers, automobile manufacturers)
  - Increased by molybdenum's reliance on the steel industry

Michelle Quitugua

Industry Economics and Structure

Industry Definition
- Copper, Gold, Molybdenum
- Copper (CU): vertical integration from ore to products (CU concentrate, cathode, and continuous cast CU rod)

Threat of **New Entry: LOW**
- High entry barriers & capital requirements
- Significant geologic challenges to find and extract minerals
- Substantial gov't policies & regulations (both U.S. and international)
- Note: Above items apply to all of FCX's business segments

Industry Definition cont.
- Gold (AU): limited vertical integration from ore to slimes/CU concentrate
- Molybdenum (MO): vertical integration from ore to products (e.g., FeMo, technical mo oxide)

Bargaining Power of **Suppliers: Moderate**
- High labor costs in U.S.
- Influence of unions in int'l labor markets
- Fluctuating logistics expenses (e.g., transportation, electricity, security, etc.)
- Impact of pending litigation over water & other resources
- Inability to forward integrate
- Producers' ability to vertically integrate
- Negotiating power of Indonesian government on Grasberg Mineral District

Rivalry Among **Existing Competitors: HIGH**
- Concentrated industries
- High exit barriers
- Significant input costs
- Little product differentiation
- Well informed buyers

Bargaining Power of **Buyers: Moderate**
- Inability and lack of desire for individual producers to behave as an oligopoly and control the global market
- Producers' ability to adjust mine extraction according to market trends
- Significant influence by Chinese demand on the global market
- Inability for buyers to forward integrate
- Producers' ability to vertically integrate

Threat of **Substitutes: Low**
- Availability of stockpiles (Cu) & recycled materials (Mo)
- Availability of materials with other *similar* properties (Mo)

Michelle Quitugua

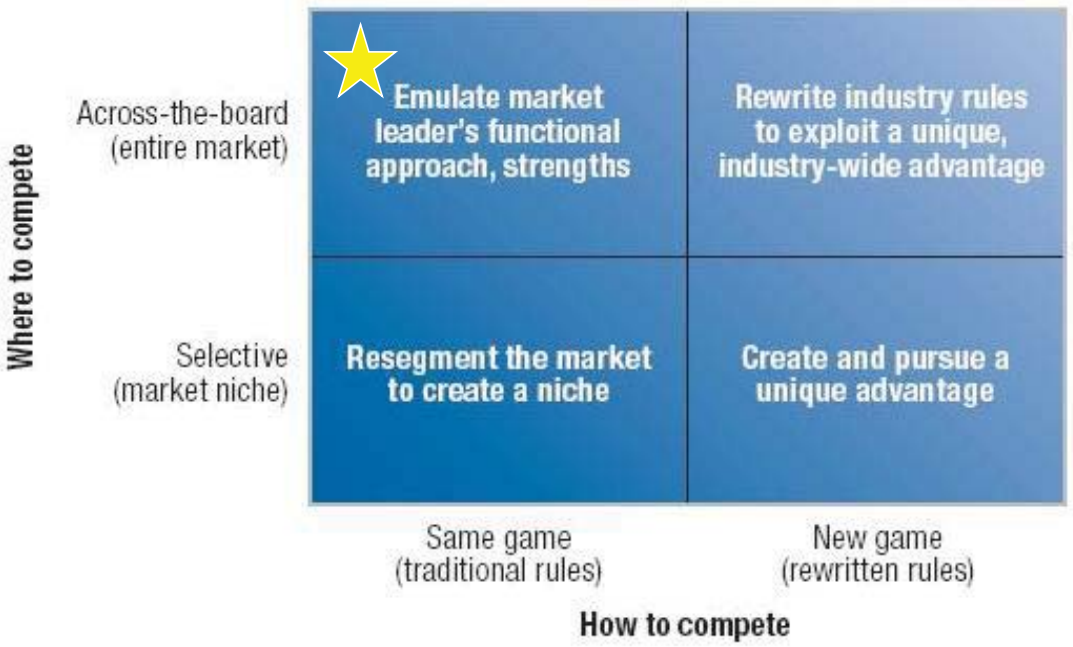
Industry Analysis: How is this changing?

- What is not likely to change:
  - High entry/exit barriers
  - High fixed costs (e.g., labor, water, electricity, etc.)
  - Geologic challenges

- What could change?
  - Threat of substitutes
    - Could gold be replace by bitcoin? If so, then gold's singular importance to the world's currencies will be gone.
  - Bargaining power of suppliers
    - Could it increase with greater labor and environmental regulations?
    - Or could it decrease with more automation and decreased labor costs?

Where & How of Strategy

Strategic Game Board

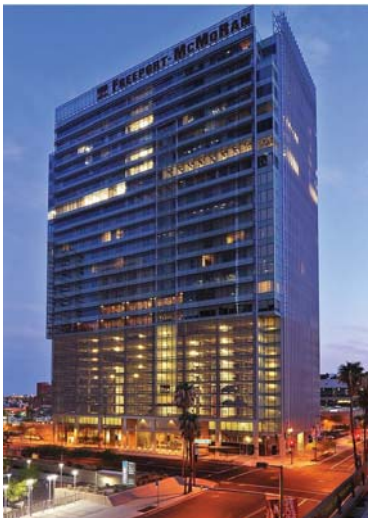


Strategic Game Board

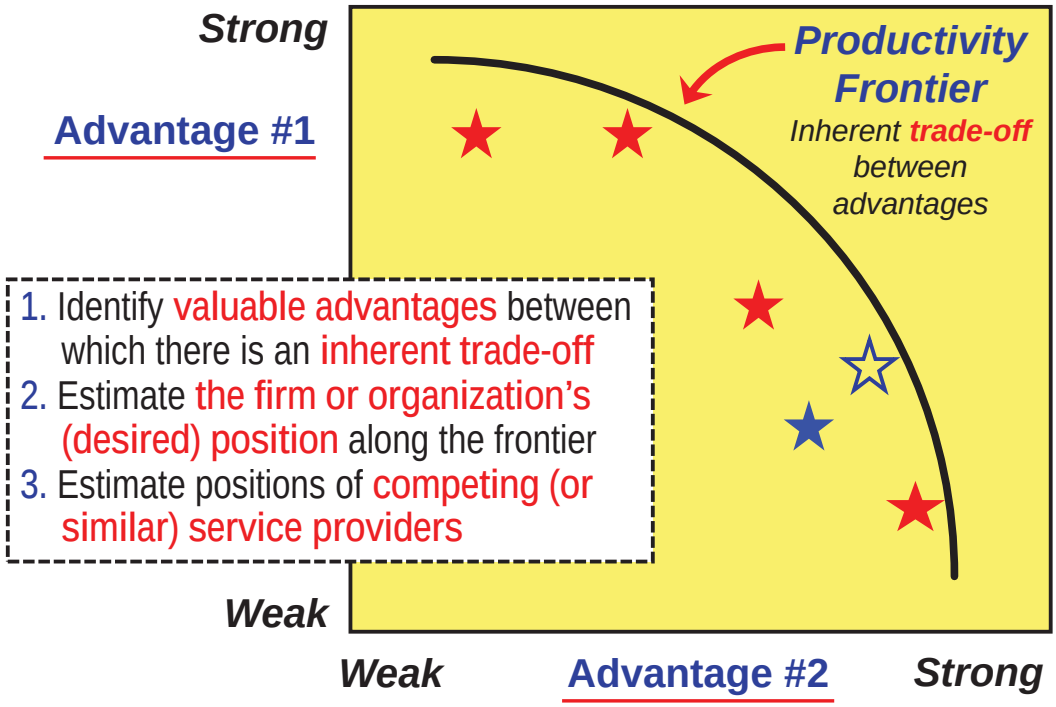
- Where does FCX compete?
  - Copper: FCX is a copper company first.
    - » Gold & Molybdenum: FCX refines the co-products/by-products that may be profitably processed and refined.
    - » Oil/Gas and Cobalt: FCX may have divested of its oil and gas interests to focus on Copper and of cobalt because of the risk of political unrest in DRC.
- When does FCX compete?
  - Long-term development and exploration
- How does FCX compete?
  - Same game with traditional rules focused on maximizing efficiency and lower unit costs

Peer Competitors

- **Public global companies**:
  - (1) BHP Group PLC $44.29B
  - (2 & 3) Rio Tinto PLC & Ltd $40.52B (each)
  - (4) Vale SA $36.58B
  - (5) Jiangxi Copper Co., Ltd. $31.3B
  - *(9) Freeport-McMoRan Inc* *$14.4B*
- **Private companies**:
  - (1) BHP Metcoal Holdings PTY Ltd $43.6B
  - *(2) Freeport-McMoRan* *$18.6B**
  - (3) Acelight PTY Limited, Cobar Management PTY Limited, Ernest Henry Mining PTY, Glencore Queensland Limited, Isokind PTY Limited, Mount Isa Mines Limited, Mount Margaret Mining, Murrin Murrin Holdings $16.04B
- **U.S. public companies**:
  - *(1) Freeport-McMoRan* *$14.4B*
  - (2) Newmont Corp $9.74B
  - (3) Southern Copper Corp $7.29B
  - (4) Coeur Mining Inc. $712M
  - (5) Hecla Mining Co. $673M



Balance of Advantages of FCX Peers

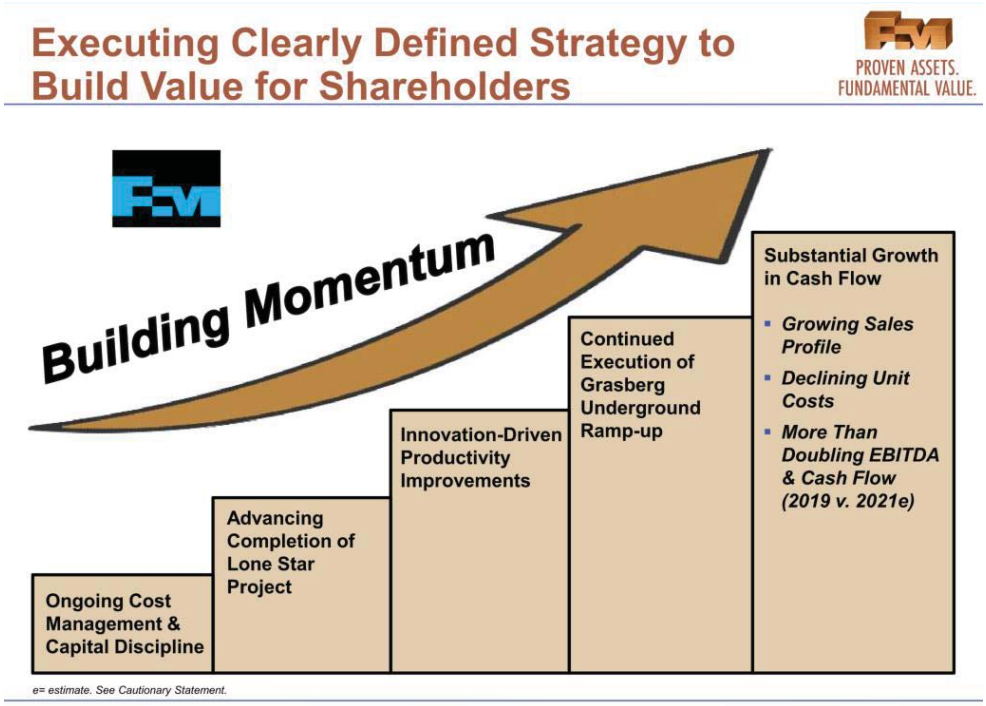


Strategy

- Three Major Initiatives
  - Support Growing Sales Profile
  - Decrease Unit Costs
  - Drive Expanded Margins & Cash Flow Generation
- Big Goals by 2025
  - Increase Copper Sales 30%
  - Increase Gold Sales 40%
  - Reduce Unit Costs 25%
  - Increase EBITDA* 100%

* Earnings Before Interest, Tax, Depreciation and Amortization (EBITDA)

Strategy



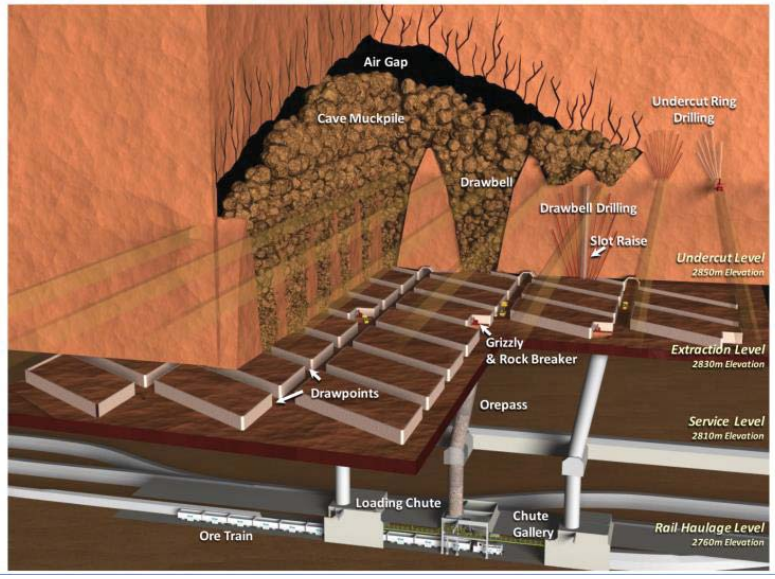
Execution

- Assumptions (Copper)
  - Strong Fundamental Outlook (before COVID-19)
  - Low Inventories in Exchange Warehouses Will Increase Demand
  - Modest Demand Increase Will Drive Prices Higher
  - Forecasted 4.4 Mt Supply Gap by 2029
  - Market Price < Incentive Price of $3.30/pound
  - Expected Market Increase From $21.2B to $24B by 2025
- Execution
  - Increase Market Share From 34% to 50% by 2025 With Expansions
  - Transition Grasberg Indonesia Mine From Open Pit to Underground
    - 40k ton/day to 240k ton/day (6X Increase!)
  - Expand Lone Star Leach Project in Arizona
    - Est. 200M pounds annual increased production
    - Will Bridge Production Gap as Grasberg Comes Online
  - New Copper Smelter In Indonesia (Joint Partnership With Inalum)

Execution

Underground Block Cave Mine Development
Grasberg Block Cave Development Diagram

PROVEN ASSETS. FUNDAMENTAL VALUE.



Execution

Lone Star Leach Project in Arizona Nearing Completion
Building Value in New U.S. Cornerstone Asset

PROVEN ASSETS. FUNDAMENTAL VALUE.

- Low-Risk Development in Established Mining District; Wholly Owned
- Located 8 miles North of Safford; 18 miles Southwest of Morenci
- First Cu Production Expected During 2020
- Estimated Production: 200 mm lbs/annum
- $850mm Initial Project (~75% Complete)
- On Schedule and Within Budget
- Oxide Expansion Opportunities with Low Capital Intensity Under Evaluation

Positive Exploration Results Support Longer-Term Potential

- Completed 202 km of Drilling Since 2015

Number of Holes	Number of Intercepts	Minimum Intercept (meters)	Cu Grade (% Cu) Minimum	Cu Grade (% Cu) Average
68	92	150	0.30%	0.56%
28	39	61	0.60%	0.82%

- Significantly Larger than Expected
- Higher Grade Zones (+0.7% Cu) in NE & SW Areas of Deposit

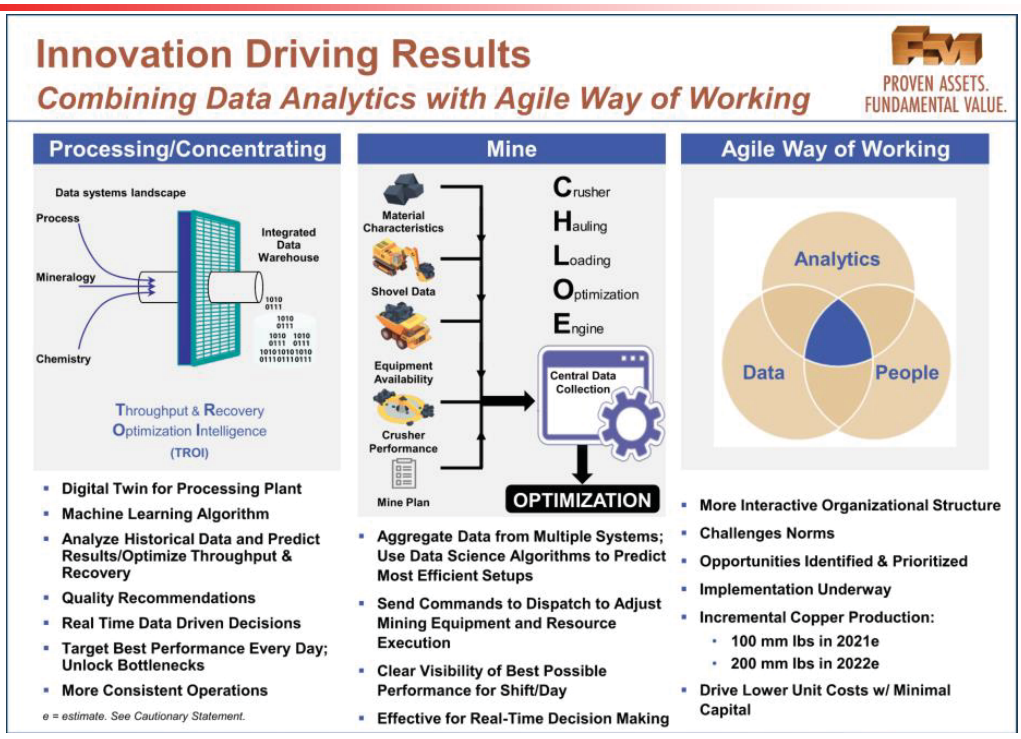
Tax-Adjusted Equivalent Copper Grade
~0.45% = 0.6%-0.7% Equiv.
(Equivalent based on 0-10% US v. 35% international tax rate)

See Cautionary Statement.

Innovation

- Investment in Automation (e.g. fully automated ore trains in Indonesia)
- Machine Learning Added to Processing of Concentrate
  - » Throughput & Recover Optimization Intelligence (TROI)
  - » Improved Quality, Increased Efficiency, Better Mineral Recovery
- AI Optimization of Mining
  - » Data Collection Throughout Entire Process
  - » Real-Time Optimization
  - » Crusher-Hauling-Loading-Optimization-Engine (CHLOE)
- Human Capital
  - » Training Staff in AGILE
  - » Integrating Big Data and Analytics Into Daily Operations
  - » Increased Efficiency With Lower Capital Costs

Innovation



Challenges

- Greater than expected headwinds in 2020 due to COVID-19
- Strategic Plan forecasts copper at ~ $2.85/lb in 2020 (currently $2.32/lb) and falling
- $9.8B in Corporate Debt may limit flexibility (comparative disadvantage)
- $1.8B in Financial Obligations for reclamation & closure
- Recent civil unrest in Indonesia, Peru and Chile
- Success of long-term strategy is contingent on completing smelter expansion in Indonesia by end of 2023
- Profitability hinges on increased future demand for electric vehicles and wind turbines
- Grasberg tailings at Ajkwa River system in Indonesia

Challenges

Tailings Management at Ajkwa Estuary

Downturn in Global Demand (Temporary?)

Value Creation

- Current Sales 2019
  - 3.3 billion pounds of copper
  - 991 thousand ounces of gold
  - 90 million pounds of molybdenum
- Expected Sales 2020
  - 3.5 billion pounds of copper
  - 775 thousand ounces of gold
  - 88 million pounds of molybdenum

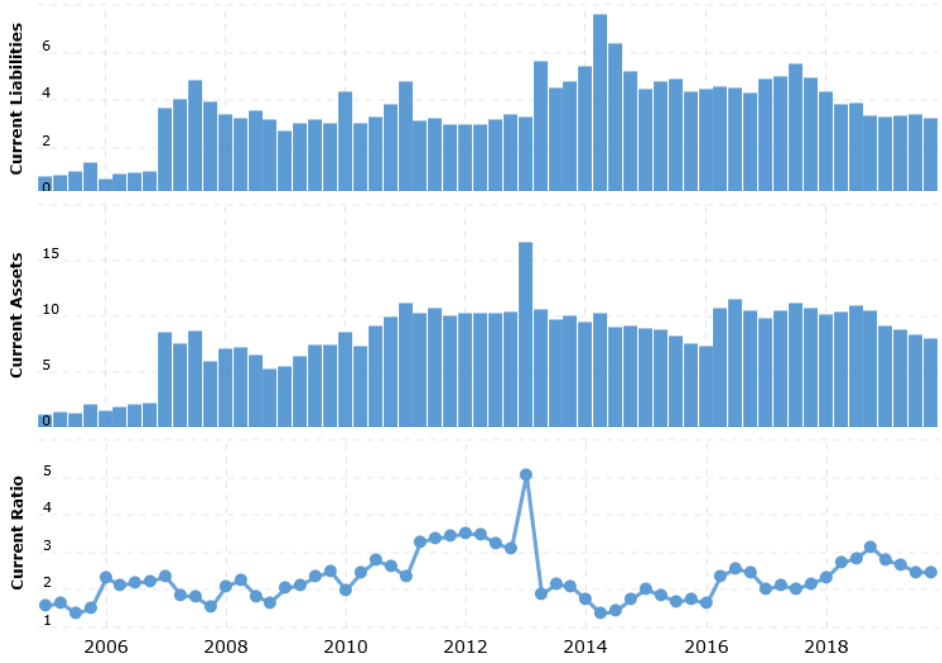
- Shareholders
  - FCX earned $3.91 billion during the 4th quarter 2019, compared to analyst estimates of $3.69 billion
- Cash Flow
  - Operating cash flows totaled $1.5 billion (including $349 million of working capital and other sources) for the year 2019
  - Operating cash flows are expected to approximate $2.4 billion (including $0.2 billion of working capital and other sources) for the year 2020

Financial Risk

- Low Risk
  - FCX's debt level at higher end of spectrum
  - Cash flow coverage adequate to meet obligations
  - Debt is efficiently utilized
    - Liabilities of $3.29B due within a year
    - Liabilities of $20.0B due beyond a year
  - Offsetting above, FCX had $2.84B in cash and $970.0M in receivables that were due within 12 months
  - During the last three years, Freeport-McMoRan produced sturdy free cash flow equating to 59% of its EBIT
  - Free cash flow puts FCX in a good position to pay down debt
  - Coronavirus impact

Financial Risk

FCX Financial Ratios in Billions $



Financial Risk

FCX Historical Debt

Firm Analysis

Strengths of Freeport-McMoRan

- Strong Free Cash Flow
- Strong Brand Portfolio
- Strong Distribution Network
- Highly Skilled Workforce
- Reliable Suppliers
- Automation of Activities
- Strong Dealer Community
- High Level of Customer Satisfaction

Weaknesses of Freeport-McMoRan

- Limited Success Outside Core Business
- Financial Planning Lacks Efficiency
- Product Demand Concerns
- Inventory High Compared to Competitors
- Integrating Firms Concerns
- Lacks Investment in New Technologies
- Marketing of Products Insufficient

Firm Analysis

Opportunities for Freeport-McMoRan

- New Customers from Online Channel
- Decreasing Cost of Transportation
- Market Development
- Opening New Markets Because of Government
- Government Green Drive
- New Trends in Consumer Behavior
- New Environmental Policies
- Organization's Core Competencies

Threats to Freeport-McMoRan

- Shortage of Skilled Workforce
- Intense Competition
- Increasing Trend Toward Isolationism
- Potential Lawsuits in Various Markets
- Changing Consumer Buying Behavior
- Rising Pay Level
- No Regular Supply of Innovative Products
- Currency Fluctuations

National Security Needs

- Domestic copper mining/production vital to DoD
- Copper - gateway metal
  - Allows access to other metals that are critical to DoD for weapon production
- Iridium, tellurium, rhenium, cobalt and molybdenum used:
  - (aircraft engines, satellites, rocket propulsion, thermal imaging, navigation systems, jet turbines and other defense systems)
- Essential to weapon systems that are crucial to US national security
- Economic welfare implications - copper is influenced by housing market
  - Remains a risk for potential market failure if housing industry had another crisis
  - Immediate financial losses could be heavy
  - Would recover once the housing market rebounded
- China
  - Global Competition
  - Impact to US
  - National Security Concern

Policies

- Firm
  - Company:
    - Avoiding Conflicts of Interest
    - Detecting Fraud
    - Protecting Intellectual Property
    - Protecting Company Assets
    - Protecting Employee Privacy/Information
  - Market:
    - Promoting Fair Competition
    - Adhering to International Trade Regulations
  - Stakeholders:
    - Respecting Human Rights
    - Protecting the Environment
    - Fighting Bribery and Corruption
    - Participating in Political Activities

Policies

- Governmental
  - Trump administration proposed more prospecting/mining of minerals
  - Essential to U.S. economy and security
  - U.S. must increase mining of critical minerals to lessen need for imports
  - Recommendations include:
    - Speeding up mine permitting
    - Doing more research of possible mining in the oceans
    - Reducing cumbersome environmental requirements
    - Weighing the need for critical minerals when it comes to consideration of mining some currently off-limit public lands
  - S. 1317
    - Bill to facilitate availability, development, and environmentally responsible production of domestic resources to meet national material/critical mineral needs
    - Bill would require the Department to develop/maintain list of minerals critical to the economic prosperity and national security of the US and improve the process of locating, developing, and using those critical minerals
  - Strategic Reserves

Materion Corporation

Industry Analysis

David Coy
Brian Ketz
Chad Livingston
Cassandra Simmons-Brown

Materion Corporation at a Glance

Materion Corporation an integrated producer of high-performance advanced engineered materials used in a variety of electrical, electronic, thermal, and structural applications.

The Company is organized into three business groups: Performance Alloys and Composites, Advanced Materials, and Precision Coatings.

Products are sold into numerous end markets, including semiconductor, industrial, aerospace and de fense, automotive, consumer electronics, energy, and telecom and data center.

Founded **1931**

Headquartered **Cleveland Ohio**

Number of employees **2,600**

NYSE Stock Symbol **MTRN**

Business Groups **3**

Annual Revenue **$1.2 Billion**

Corporate Leadership

Global Reach **50 countries served**

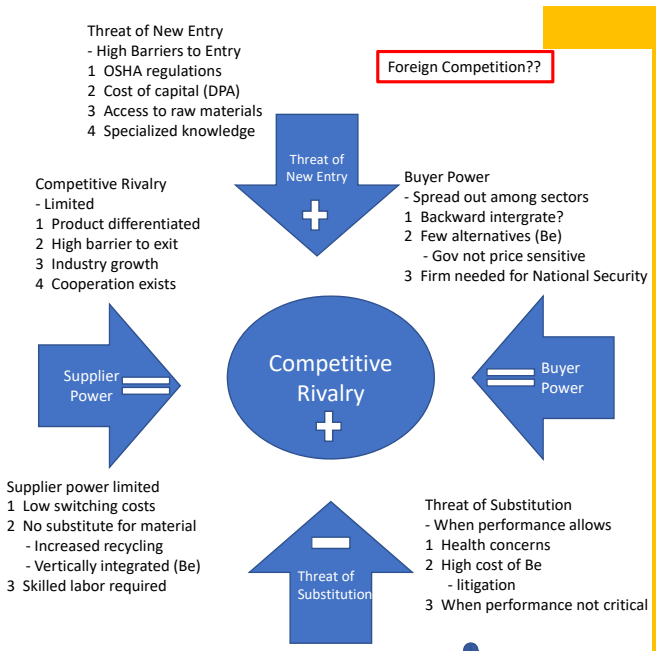
Worldwide Locations **32**

Business Environment: Is Materion a Beryllium Company or High-performance Advanced Engineered Materials Company?

- Supplies over 70% of the worlds' mined beryllium.
- 75 years of proven reserves in Utah mine.
- Only global vertically integrated producer of beryllium.
- 40% of company sales included beryllium in some form.
- See themselves as a high-performance materials company, not a commodity company
- Switching focus: service oriented rather than just product oriented.
- Increasing R&D capabilities and resources to meet market demand for quick turn prototypes and new material demands.
- Increasing new product development and services to meet similar customers' needs in different ways
- Collaborating with competitors to increase the market size rather than just competing for small market (process management)

Competitive Position Analysis

- **Supplier Power:** Limited due to low switching costs for raw materials, own supplier for Be, and increase in the recycling sector – precious metal costs "passed through" to customers.
- **Buyer Power:** Buyers spread among different sectors with few alternatives for Be products: substitutes may be used only when performance not critical.
- **Threat of New Entry:** Little threat of new entry domestically....foreign competitors, specifically China, could decrease prices as they try to gain market share. (No OSHA)
- **Threat of Substitution**: The Beryllium market is heavily regulated; coupled with its high cost, drives the use of alternative materials when performance not critical. . . risk to firm if US Gov doesn't require Be for National Security.
- **Competitive Rivalry:** Limited competition within Be market, highly differentiated with industry growth expected.



Materion is positioned to support the demand Be products for the foreseeable future and has incremental profit potential due to growth of industry & limited competition

Competitive Advantage

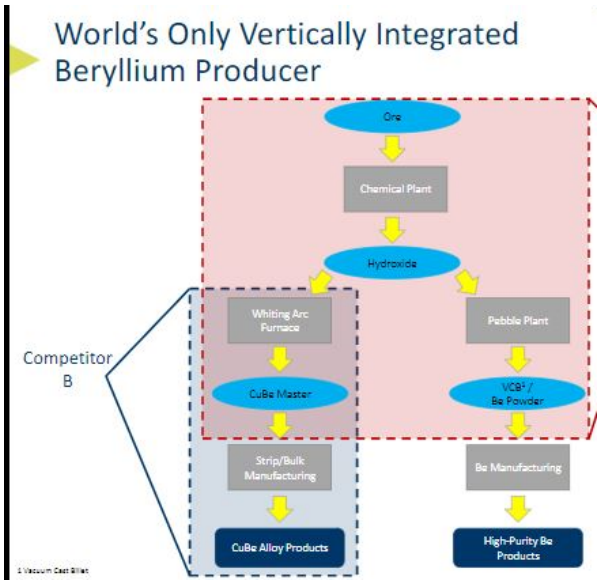
Reliable suppliers

Strong distribution network

Automation of activities

Integrating complimentary firms through mergers & acquisition

Product innovation



Materion Corporation, "Materion Corporation 10-K," Annual report, United States Securities and Exchange Commision, December 31, 2018.

Key Strategic Questions & Elements

Key Challenge: Environmental, safety, and labor costs make Be more expensive to produce in the U.S. than in China and other potential supplier countries.

Strategic position: Focus on differentiation with custom products in high-performance applications. Where efficiencies permit, compete in more commonly used alloys. Operate in legacy domestic locations in Utah and Ohio with globally-dispersed service offices.

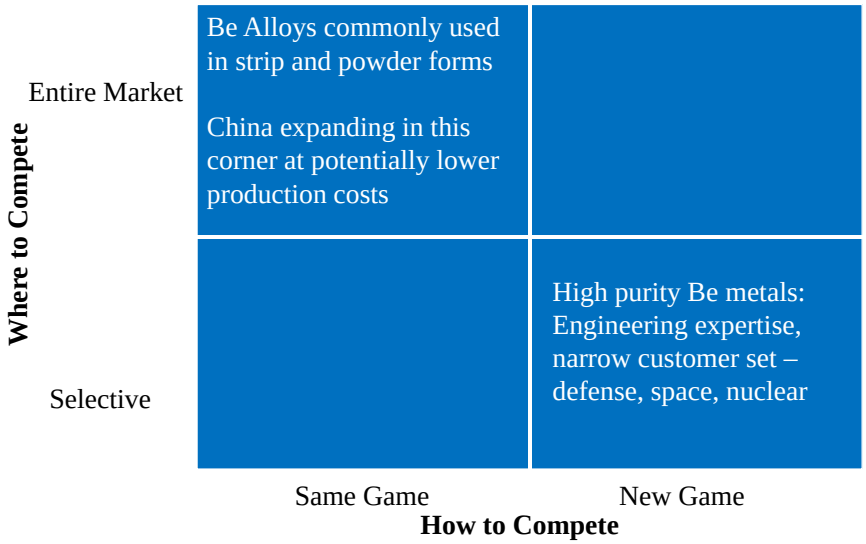
How: Vertically integrated from mine to machined product to capture value throughout the chain. Produce custom engineered Be products for high-performance end uses. Capture and maintain large market share for customers with high willingness to pay for performance-critical applications.

Diagnosing the Challenge

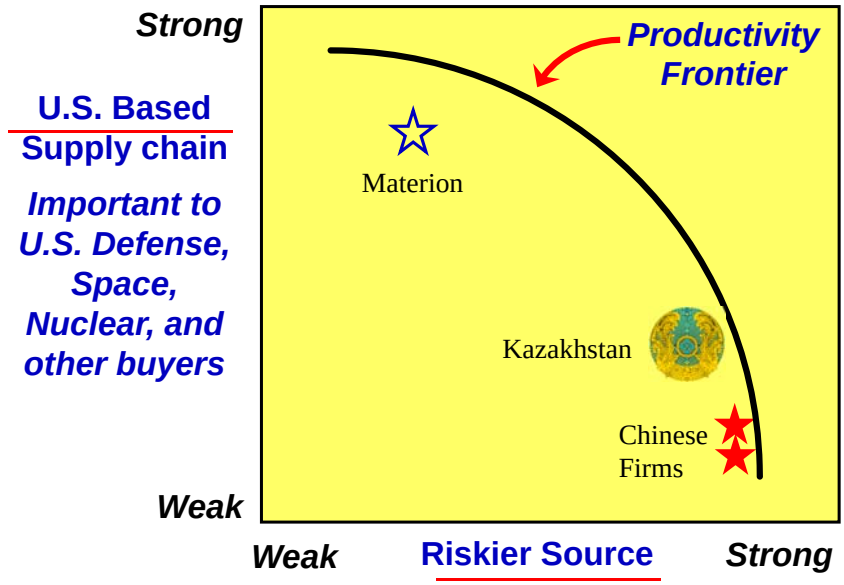
Challenge	Why So Difficult?
▪ Mine Be metal ▪ Mill Be metal ▪ Convert Be metal ▪ Extract Be metal ▪ Process to powdered Be	▪ Strict Safety and Environmental requirements in U.S. ▪ Relatively high cost for labor ▪ Cannot compete on efficiency in a commodity market
▪ Casting and machining Be	▪ Strict Safety and Environmental requirements in U.S. ▪ Relatively high cost for labor
▪ Selling high-performance space, defense, and aerospace components overseas	▪ Export documentation requirements discourage potential customers

Where & How of Materion Strategy

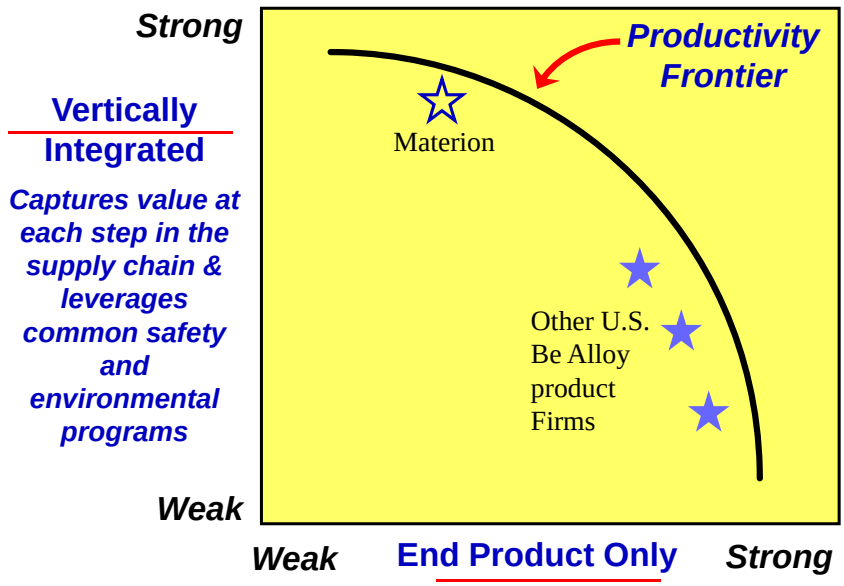
Strategic Game Board



Balance of Advantages International



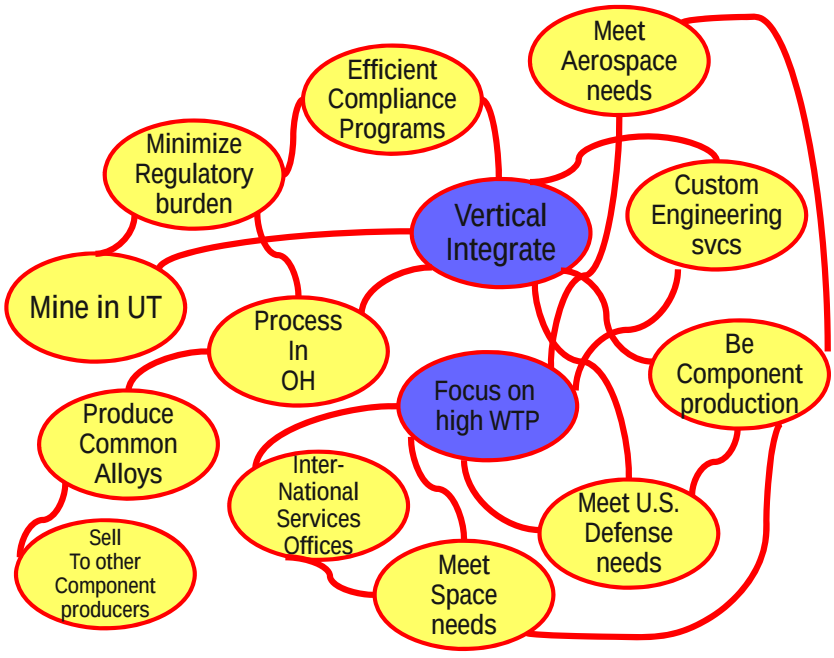
Balance of Advantages Domestic



Strategic Position: Scope Choice

Products or Services *Variety-Based Position*	Channels or Locations *Access-Based Position*	Customers or Users *Needs-Based Position*
DO ▪ Focus on performance-critical products ▪ Produce more common alloys as efficiencies allow DON'T DO ▪ Compete strictly on commodity or efficiency	DO ▪ Perform engineering services in worldwide offices ▪ Mine in Spor Mt ▪ Process in OH DON'T DO ▪ Mine outside Spor Mt ▪ Process outside OH	DO ▪ Serve high willingness to pay customers ▪ Meet U.S. supply-chain needs of defense and other customers DON'T DO ▪ Cater to Chinese markets

Activity System Map



Internationalization & Global Strategy

Integration / Responsiveness Framework

HIGH PERFORMANCE SPECIALTY ALLOYS

GLOBAL STRATEGY *Role of Subsidiary:* Implement HQ Strategy	**TRANSNATIONAL STRATEGY** *Role of Subsidiary:* Contribute to Global Advantage of MNC
INTERNATIONAL STRATEGY *Role of Subsidiary:* Sell HQ Products	**MULTINATIONAL STRATEGY** *Role of Subsidiary:* Identify & Exploit Local Opportunities

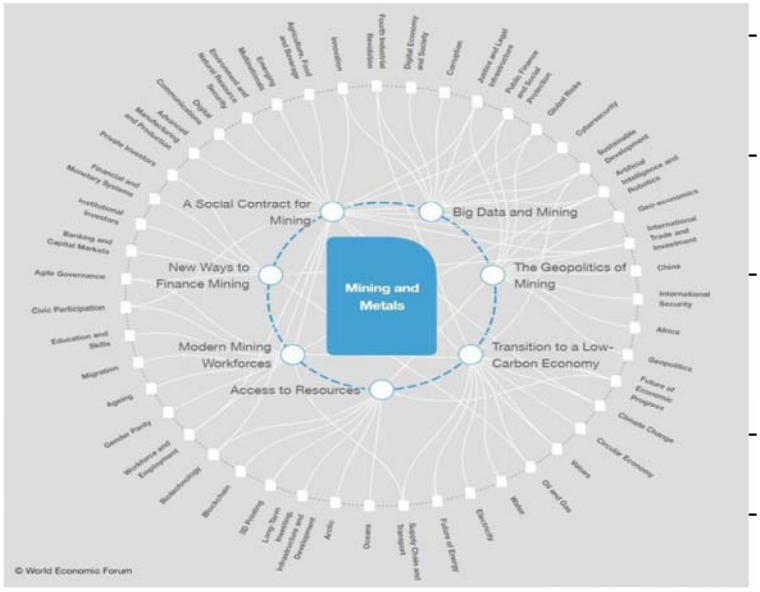
HIGH

Forces for **Global Integration**

LOW

LOW — Forces for **Local Responsiveness** — HIGH

Challenges in Mining & Metals Industry – Firm View



Mapping the connections in mining

Image: World Economic Forum

http://indiaenvironmentportal.org.in/files/file/WEF_MM_Sustainable_World_2050_report_2015.pdf

- Availability and access to raw materials
- Cut costs, increase automation & improve operational efficiency
- Mitigate risks - regulation, geopolitical, legal limits on natural resource use
- Public opinion about environment
- **Value to shareholders**

Potential Disruptions

- Lower demand (Material Substitution & Recycling)
- Geopolitics & access to export products
- Technology/Automation (Mine & Processing Plants – large capital investments

- Labor (Aging Workforce)
- Health & Safety
- Regulations/environmental disaster

Materion: By the Numbers

Facts:

Based on its operating costs and revenues Materion is profitable.

- Net Sales ($1.2 billion) and Value-added Sales ($733.7 million) remained flat in 2019 compared to 2018 but grew slightly over the last 5 years.
- 2019 Operating profit was $67.0 million; adjusted operating profit improved 25% from prior year to a record $82.4 million; Operating cash flow was a record $99.2 million.

Materion Return on Assets, Return on Equity, and Revenues Per Employee shows the company as efficient but being out-performed by the industry.

Materion uses little to no debt to fund their capital structure (byproduct of the Defense Production Act Title III Program). Debt has increased in the last 2 years.

Materion pays an annual dividend, which is unique in the mining industry.

Materion has strong free cash flows that provide resources in the hand of the company to expand into new projects.

Concerns:

Sales were flat but operating profit is up (short-run efficiencies or market diversification (multi-pillar strategy))

ROIC and WACC gap is closing.

Threat of substitutes and new supplier (China).

Slow down of the global economy, including the impact of tariffs and trade agreement.

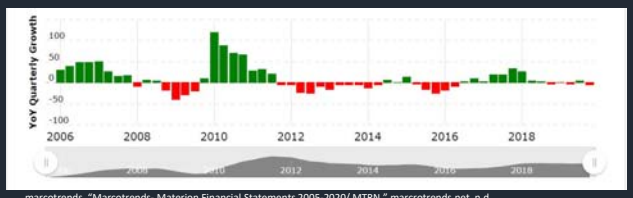
Value Creation Analysis:
Is Materion a Beryllium Company or a High-performance Advanced Engineered Materials Company?

- Materion demonstrated they were a high-performance alloys company following the decommissioning of the beryllium reduction plant in 2000
- Materion received economic benefit from the injects of funds from DPA for reduction of Beryllium
- Materion owning all parts of the values chain (vertically integrated) provides them significant incremental profit potential
- Materion is positioned to remain profitable in the coming years if the reduction requirement continues and there is a critical need in high demand high performance alloys and composites.

Bottom-line:

- As residual economic effects of the DPA inject wear out and the threat of substitutes increase, Materion is at risk, unless they continue to create efficiencies in their organization and/or diversify.
- Materion must increase new product development and services to meet similar customers' needs in different ways than the past in order to be profitable in the long-term.

Revenues



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Net Income

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Implications for National Security & Industrial Policy

- Overall the market is healthy, and government should support minimal interventions
- "Form and concentration of material" affects time to deliver product to meet surge or mobilization requirements.
  - Be stockpile form to avoid pebble-plant bottleneck
  - Fund design for plant expansion
- Tax breaks to support machine upkeep and replacement
  - Better positioned for surge or mobilization

Implications for National Security & Industrial Policy

- Likely will need more DPA Title III Program funding due to increased OSHA/ environmental regulations
  - Under Section 303 received property rights to capital investments (i.e. infrastructure & equipment) Pebble Plant.
- Keep contract commitments
  - Open BAA/contract with DLA Stockpile
  - Reduce the amount DLA Stockpile disposes (i.e. 8 ST = 16,000 Tons) (FY20 – FY24).
- OSD Industrial Policy
  - Speed up ITAR license process

NATIONAL DEFENSE UNIVERSITY

Albemarle + Lithium

Structure • Conduct • Performance • Policy

Our Team

Sangano Wibonela
Sasa Konjevic
Matt Oskam
Paul Harrison

Industry Analysis

Agenda

- Firm History
- Industry Five Forces Analysis
- Balance of Advantages/Activities/Trade Offs
- Strategy and Approach
- Financial Performance Analysis
- Overall Assessment and National Security/Industrial Policy Recommendations

Firm / Business Unit History

- 1887: Albemarle Paper Co. founded in Richmond
  - Makers of Kraft paper from chemical pulp for packaging, grocery bags, electrical insulation
- 1917: Charles Kettering discovers gasoline additives to reduce engine “knock”
- 1920s: Kettering + GM + Standard Oil create Ethyl Gasoline Corp. to manufacture additives
- 1950s: Albemarle president sees threats to paper market, seeks polyethylene option (drycleaners)
- 1962: In largest ever Leverage Buy-Out to date ($200 million) Albemarle buys Ethyl
  - “Jonah Swallows the Whale” headlines

Paul

Firm / Business Unit History

- Albemarle becomes subsidiary of Ethyl
- 1980s: acquisitions & diversification (Oxford Paper, insurance, Visqueen, plastic bottles, aluminium)
- 1994: Albemarle spins off Ethyl’s chemical processing units as publicly traded company
  - Used IPO proceeds to procure chemical plant in England and sign joint venture with Jordan Dead Sea Industries company (bromine).
- 2015: Bought Rockwood Holdings from KKR ($6.2B) for Lithium business
- Now runs three unique business units (lithium, bromine & catalysts) located around the world

Paul

Albemarle's Big 3

Catalyst Unit

- Makes specialty catalysts for production of hydrocarbon products like aviation fuel, plastics, clean fuel technologies
- Market leader in fluid cracking catalysts and clean fuels technology
- Benefits from increasing fuel standards

Bromine Unit

- Key fire retardant for electronics (5G), housing
- Control of world's best bromine sources = low cost advantage

Paul

Albemarle's Big 3

Lithium Unit

- Newest Albemarle business unit (2015)
- Focus on demand for energy storage
- Control of world's best lithium sources = low cost advantage
  - Hard rock lithium mining in Australia, NC
  - Brine lithium extraction in Chile, Argentina, NV

Challenge is delivering low cost (or certain cost) to producers and meeting changing demands as power storage requirements develop – while staying ahead of increasing global supply from competitors

Paul

Industry Economics & Structure

Bargaining Power of Buyers

- About 44% of revenues are generated from lithium battery resulted from domestic electrical vehicle manufacturers, many companies manufacture both batteries and electric cars, these include Tesla, Ford, Nissan, GM, all source lithium from LG Chem, at the same time, Tesla company has in contract supply with Panasonic lithium battery, so, Nevada lithium company will supply more batteries due to many companies buy lithium battery from Nevada.

Bargaining Power of Suppliers

- The Mine Albemarle Silver Peak is the main Lithium metal supplier. E.g. in 2015 produced 6,000 metric tons of lithium carbonate. Equivalent to 3.42% global supply.
- There is an increase demand of lithium battery due to increase in demand for electric cars.
- Increase in price due to increase in electrical cars, has attracted new entrants.

Industry Economics & Structure

Rivalry among Competitors

- Rivalry among competitors are driven by product quality, product diversity, reliability of supply and consumer services. Profit being a determinant factor.
- For example, Nissan firm is a dominant in electric cars market, hence, has the power to determine price of the market, meanwhile, Tesla Company takes a market for luxury electric cars, so it determines price for that market. So, customer affordable for luxury vehicle can shift from electric vehicles to luxury one.

Threat of New Entry

- Threat of New Entry affect much the earning of the return on Capital of the firm when comparing with cost of capital.
- Barrier to entry is a determinant factor to new entry, it is weighed in terms of capital requirements, which is all about technology intensive and it requires at least medium level of start up capital for purchasing machines and equipment for production, skilled workforce, training for workforce and Research &Development.
- Economics of Scale & Absolute Cost Advantages. E.g. lithium battery patented technology to lower the cost of Kilowatt

Industry Economics & Structure

Threat of Substitution

Threat of substitution goes with supply and demand law of the market. For instance, when the price of fuel rises, then the demand for electric cars increases which makes an increase in lithium battery. So, Lithium batteries drives the demand for electric cars when fuel goes up.

Complements or Other Factor

- Substitute for lithium compounds is possible in batteries, ceramics greases, and manufactured glass. For example, calcium, magnesium, mercury and zinc are raw materials for primary batteries .
- Sometimes customers switch to another products, especially to those which are not subject to infringement suit.

Industry Economics & Structure

Industry Definition:
- Global lithium production

Threat of New Entry: Low
- Large capital costs (except for China?)
- Limited productive mining rights
- Overly saturated market

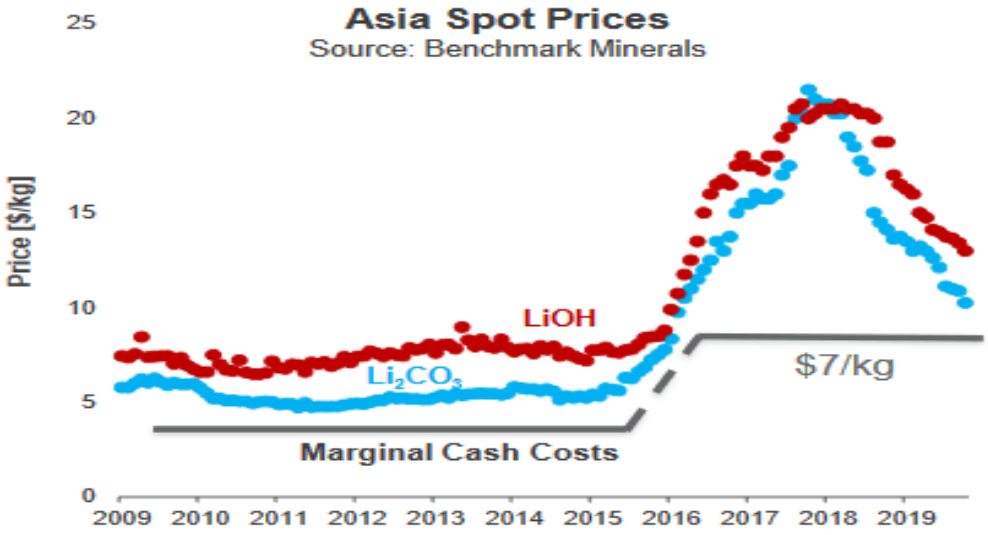
Bargaining Power of Suppliers: High
- Suppliers concentrated: "Lithium Triangle"
- Switching costs are high
- Impact of inputs on cost is high (water rights and royalties)

Rivalry Among Existing Competitors: High
- Commodity market
- Switching costs are low
- Overcapacity in supply with future expansion
- High fixed costs relative to marginal costs
- Diversity of competitors with state interests

Bargaining Power of Customers: Mixed Bag
- Global demand projected to triple by 2025
- Commodity market but currently oversaturated
- Buyer switching costs are much lower relative to firm switching costs
- Backwards integration hard due to supplier power

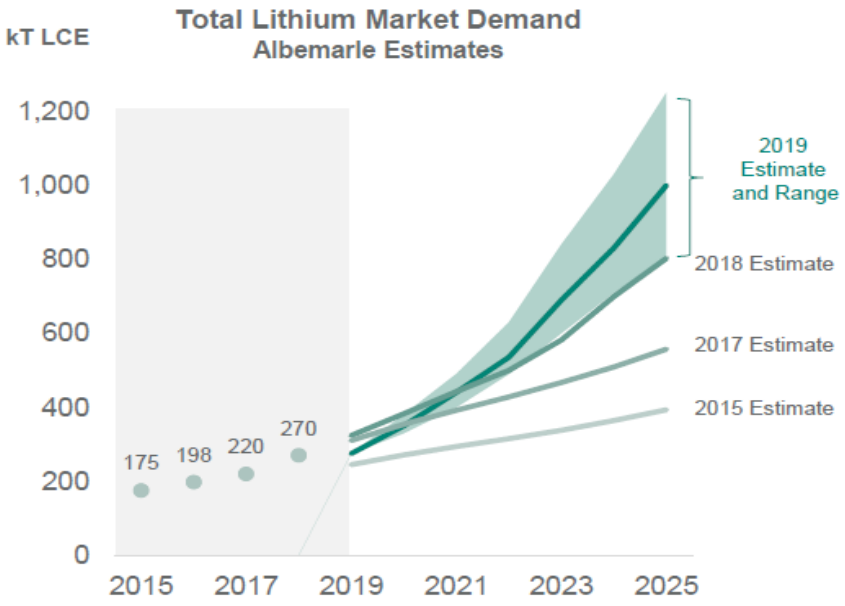
Threat of Substitutes: Low
- Lithium is battery of choice: higher energy density and power
- Switching costs are high with low buyer propensity to substitute

Would you enter this market?



Wibo

How about now…?



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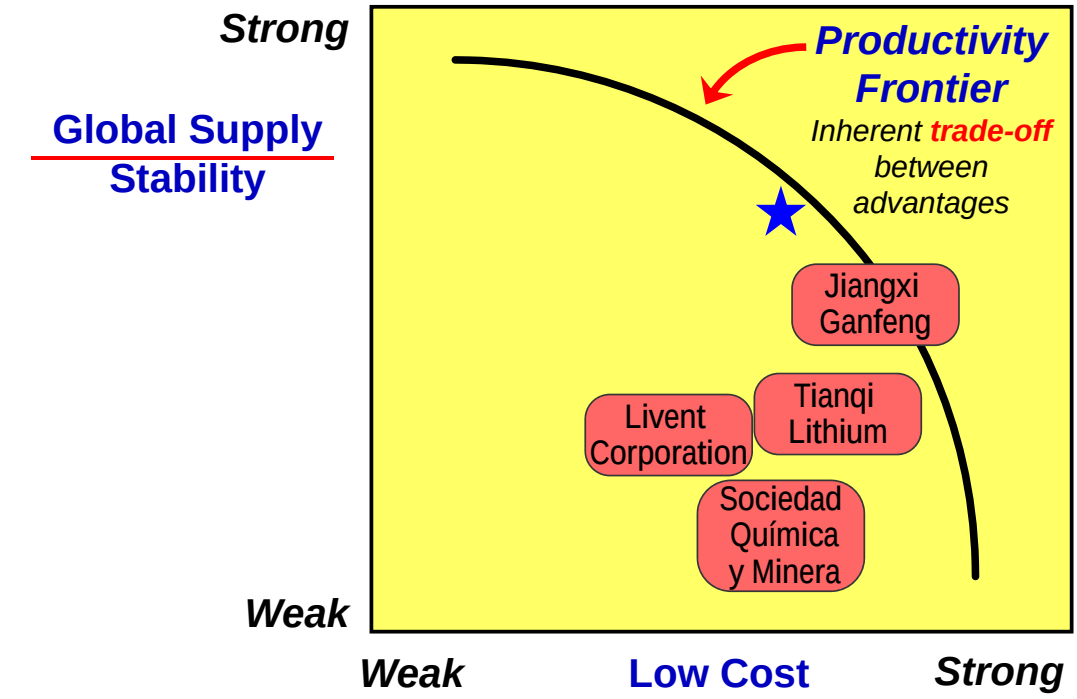
Balance of Advantages at Albermarle Lithium Business Segment



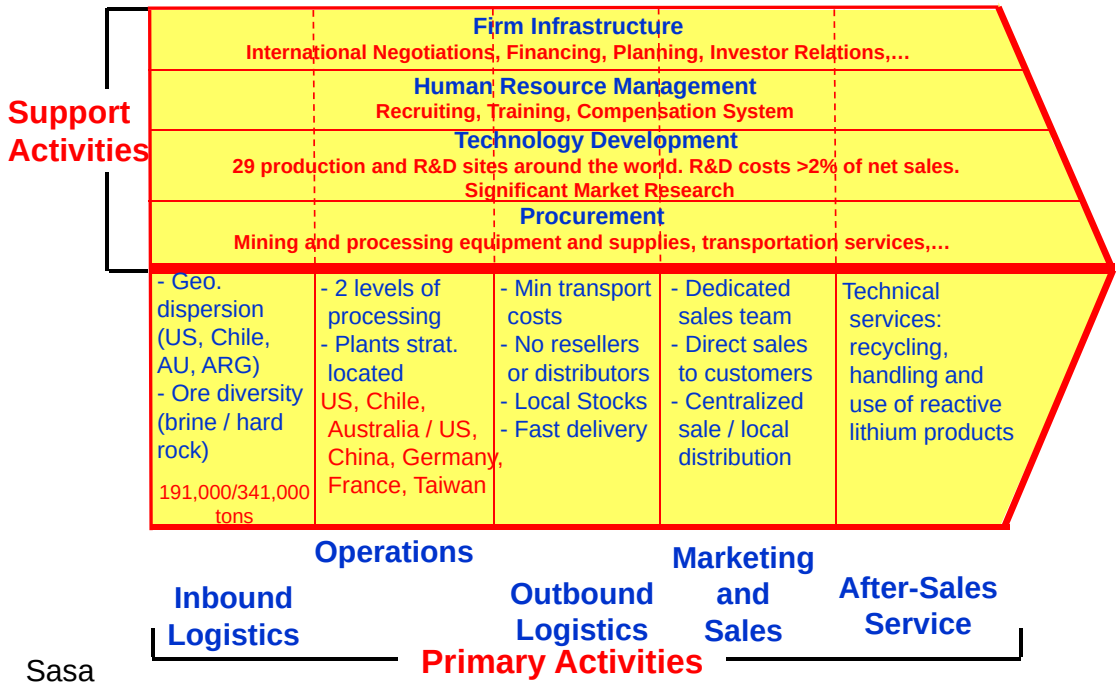
Sasa

Distinct Activities & Trade-Offs

Distinct Activity	Value	Trade-Off
▪ Variety of products	▪ Wider customers' pool	▪ Lack of specialization ▪ Higher cost
▪ Vertical Integration	▪ Lower production costs ▪ More independent ops	▪ Higher cost
▪ Geographical dispersion: raw materials and processing facilities	▪ "Think globally, act locally" ▪ Supply stability ▪ Price control	▪ Huge investments ▪ International negotiations
▪ In-house R&D	▪ Maintain tech-edge over competition ->▪ Maintain industry leadership ▪ Creates dependence of competition on us	▪ Increases costs

Sasa

Cataloging Activities: The Value Chain



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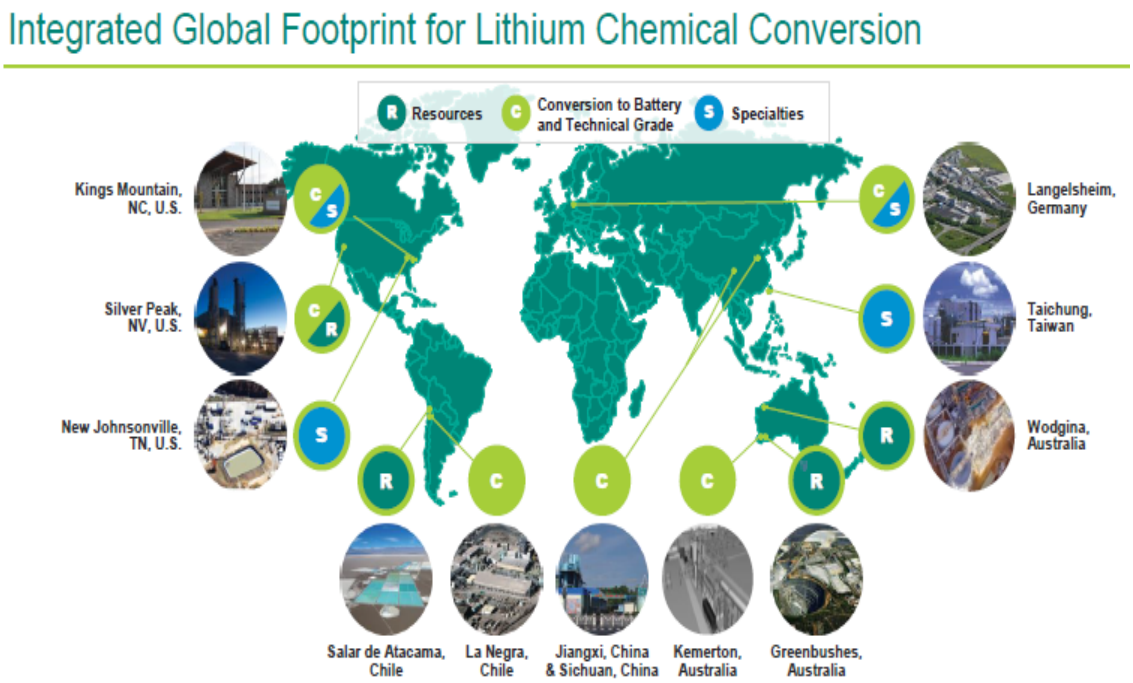
Diversified, Worldwide Operations



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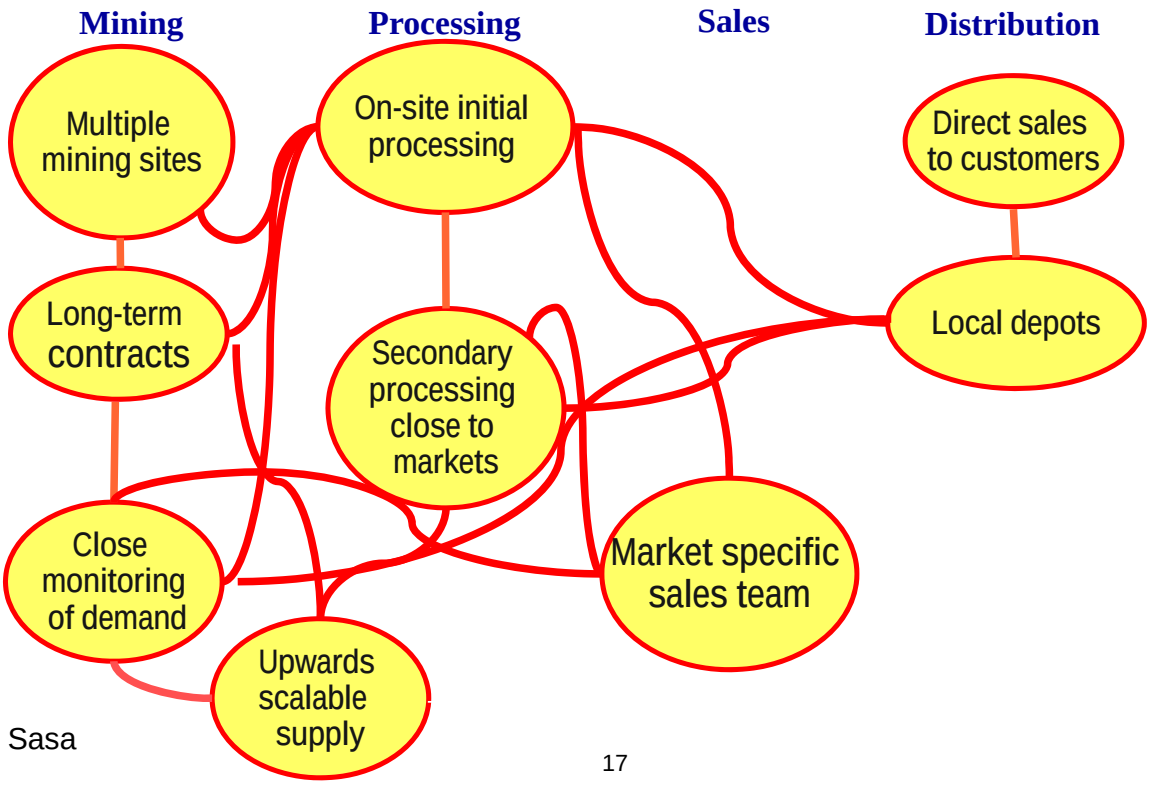
Activity System Map



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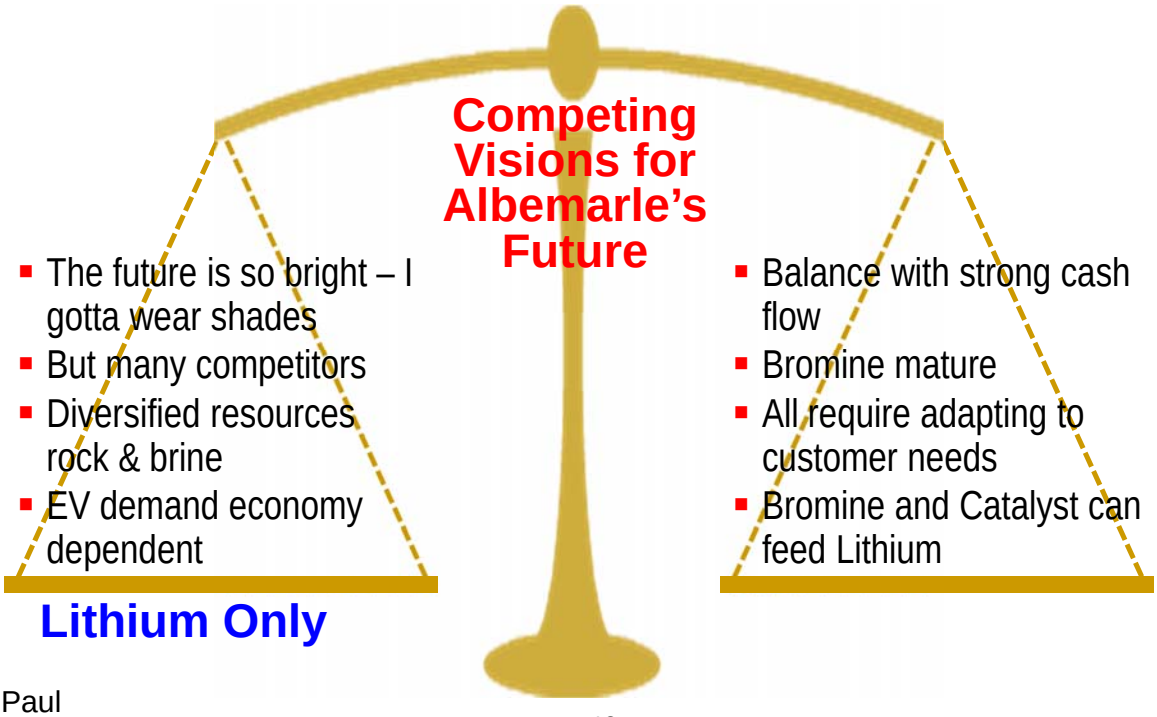
Our Dilemma: One Focus or Three



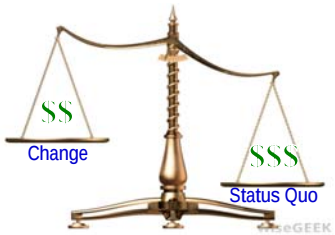
Paul

Potential Firm / Industry Inertia

- **Cognitive Inertia**
  - Albemarle has survived by changing

- **Action Inertia**
  - Albemarle perceived lithium opportunity and acted
  - But did they see other entrants?

- **Incentive Inertia**
  - Given growth of lithium production and stalled demand should they go all in or not?



Approach to Corporate Advantage

- Portfolio Management
  - Rockwood acquisition was chance to diversify across business units, leverage ability to produce specialty chemicals to meet changing client needs – at low cost!
- Restructuring
  - Albemarle itself has restructured many times – from paper company to LITHIUM
- Sharing or Transferring Activities
  - Partnerships w/ Exxon (catalysts)
  - Lithium development P-ships

Albemarle's Decision Drivers

- What We Do Well (i.e. "Make")
  - Top-level Specialty Chemical producer
  - Expertise to be responsive to client needs
  - Wide-range of products and industries
    - Agricultural compounds
    - Drilling compounds
    - Cleaning products
    - Lithium (2015)
    - Catalysts (plastics, polymers, refining)

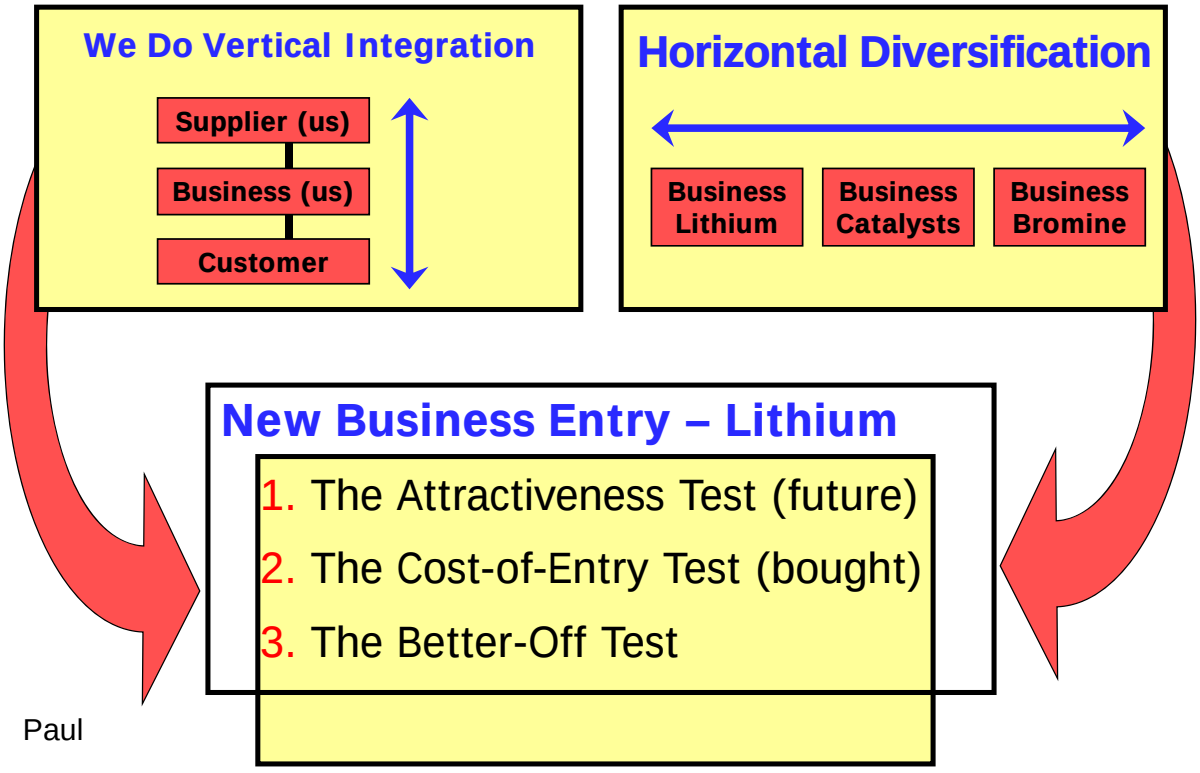
Paul

Decision Drivers Part Deux

- What We Have Bought/Do Not Do Well
  - We own bromine and lithium resources BUT
  - We buy inputs for catalyst business
- Bought LITHIUM business in 2015
  - Purchased from KKR for $6.2 billion
  - Now leading LI producer
  - Working to increase efficiency

Paul

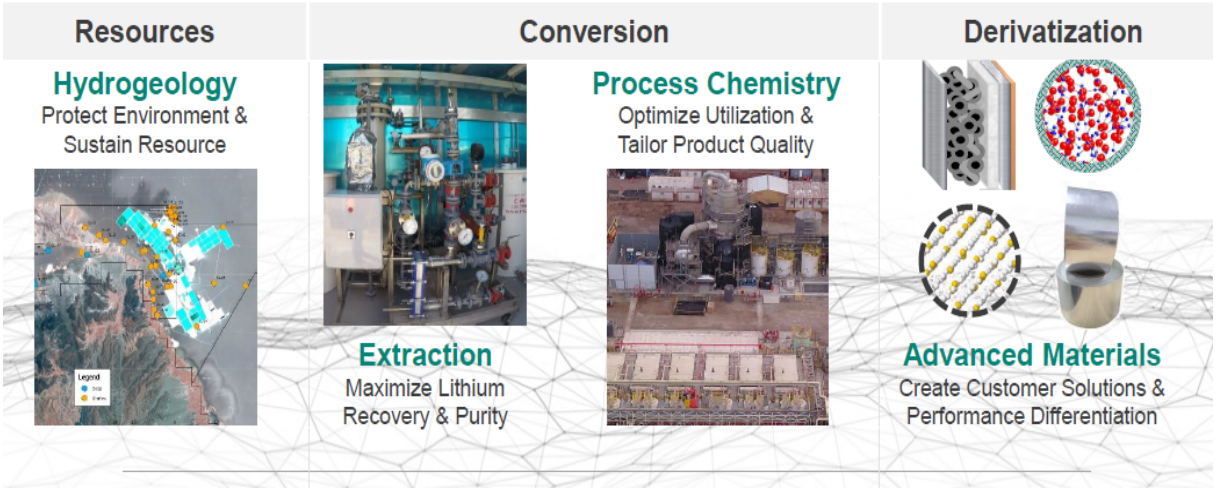
Albemarle's Approach



Paul

Lithium Vertical Integration

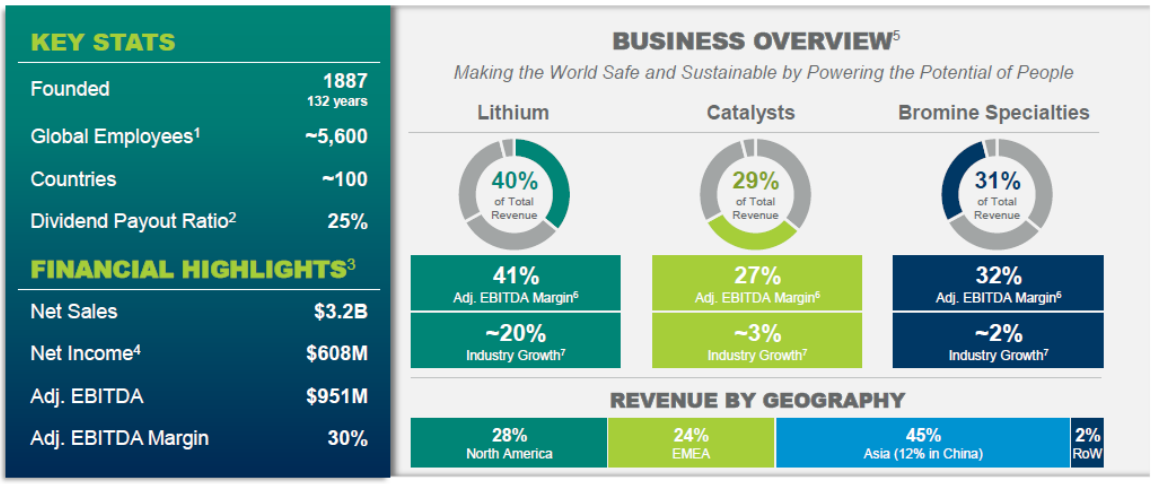
Technology Innovation: Spanning from Minerals to Market



Paul

Horizontally Diversified Portfolio

Diversified Portfolio with Above-Market Margin



Paul

Financial Performance

Does Albemarle create value at an acceptable level of financial risk, relative to their competitors?

Matt

Value Creation Questions

- Is Albemarle investing capital from investors to generate future cash flows at rates that exceed the cost of capital?
- How do they compare to their competitors?
  - Diversified vs. 100% lithium
  - Global vs. local mining operations

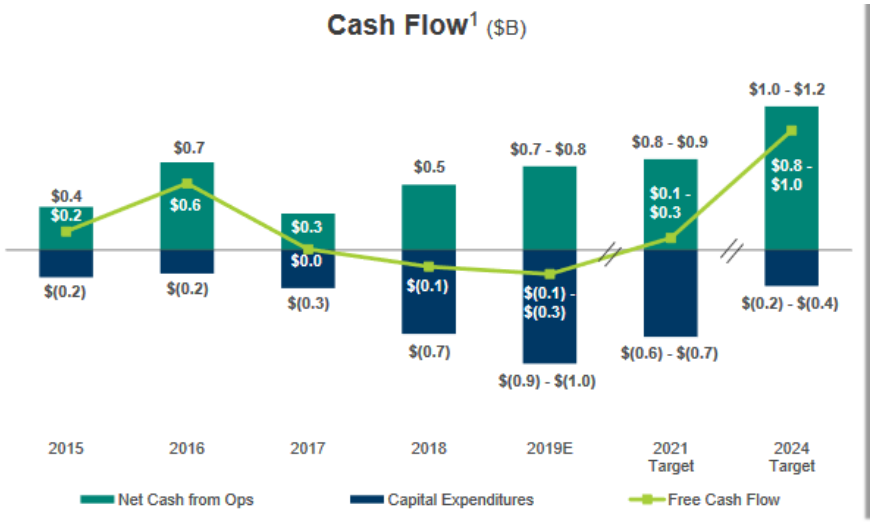
Matt

Value Financial Ratios & Measures

Measure	ALB	SQM	LTHM	Interpretation
ROIC	9.8	7.8	13.7	▪ Strategies: ▪ Diversified vs. Single ▪ Global vs. Local Mining
Operating Margin	18.5	22.31	15.09	▪ Multi-year pricing > Spot Market?
Free Cash Flow	- $132.4M	+$105.6M	- $126.2M	▪ Multi-year pricing allows cheaper credit for expansion.

Matt

Free Cash Flow



Matt

Financial Risk Questions

- Is Albemarle creating value at unnecessary financial risk?
- What is their ability to pay their bills now (liquidity) and over time (solvency)?
- Are they over leveraged?

Matt

Financial Risk Ratios & Measures

Measure	Albemarle	SQM	LTHM	Interpretation
Current Ratio	1.57	1.47	2.2	▪ Standard
LT Debt to Total Equity	72.7	70.3	106	▪ Stand alone requires heavy greenfield investment
Interest Coverage Ratio (Zombie Check)	15.85	8.89	>400	▪ Spin off allows access to capital vs LT debt.

Matt

Financial Performance Analysis

- Diverse portfolios and multi-national operations reduce risk and enable expansion
  - Increased Capital Provides Foundation
    - Allows expansion supported by long-term lithium price agreements. Capital allows you to ride the wave. *If LT debt is too costly, spin off new IPO.
  - Reduction in Commodity Price Risk
    - 50% of ALB's revenues come from diversified bromine and catalyst businesses
  - Reduction in Operation Risk/In-country flareups
    - Argentina environmental water rights
    - Chilean offsets and royalties

Matt

Firm Analysis Summary

- **Industry Environment**
  - Tough industry to join
  - Prices near trough
  - Future demand projections are favorable
  - Chinese vertical integration threat?
- **Strategic Position**
  - Advantage: Global low cost at scale.
  - Scope: Bromine, Catalysts and Lithium
  - Activities: Diverse horizontal and vertical in key value areas

Firm Analysis Summary

- **Corporate Strategy**
  - Vertical Integration in value creating areas
  - Horizontal Diversification across chemicals
- **Global Strategy**
  - Globally integrated, top-level specialties
- **Financial Performance**
  - Diversification allows stability with flexibility to grow
  - If credit becomes tight, spin off into a pure lithium firm will allow expansion

Overall Assessment & Evaluation

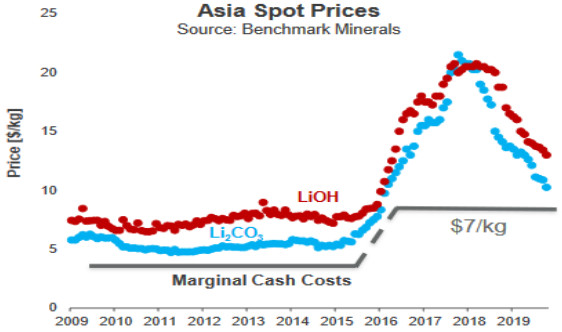
- Firms with diverse and independent portfolios can withstand commodity price fluctuates
  - Stability plus Flexibility
- Diverse mining locations can mitigate “restructured” mining and water right permits

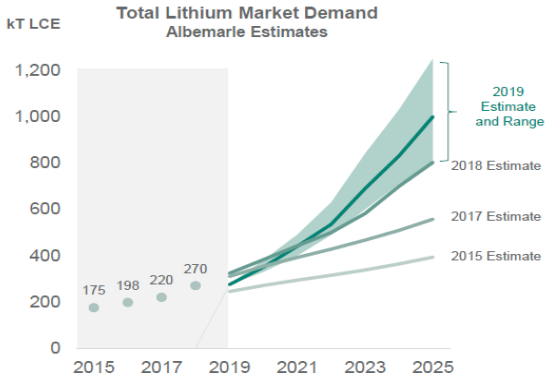
Implications for National Security

- Stable and predictable international political and trade relations are crucial
  - 74% of Albemarle’s sales are to foreign countries, 80% of mining is international
- Excessive regulatory and environmental hurdles will reduce sales

Implications for Industrial Policy

- With global demand projected to triple by 2025, DLA should stockpile lithium now.
- Due to supply oversaturation, long-terms contracts will ensure long-term supply availability by encouraging expansion





Group