World Economic Forum
Digital Transformation Initiative
In collaboration with Accenture

MINING AND METALS INDUSTRY
EXECUTIVE SUMMARY
JANUARY 2017
Digital transformation is emerging as a driver of sweeping change in the world around us. Connectivity has the potential to empower millions of people, while providing businesses with unparalleled opportunities for value creation and capture.

Within the mining and metals industry, digitalization will be a force that changes the nature of companies and their interaction with employees, communities, government and the environment at every step of the value chain. From mineral exploration and valuation, through mining, ore processing and metals production, to downstream sales and distribution, digitalization is blurring traditional industry lines and challenging the business models of the past.

For companies that embrace digitalization, it offers the promise of a more nimble and profitable business, with improved decision-making and increased employee empowerment. More importantly, when designed and implemented correctly, digitalization can improve health, safety and environmental impact – saving lives, reducing injuries, lowering emissions and waste, and increasing transparency and sustainability.

It is clear that digitalization will be a source of transformational change, but there are a number of challenges that need to be overcome. In many cases, the gains from digitalization have been inequitable, with the benefits not reaching those who need them most. As technology empowers some workers and creates new jobs, it could also threaten traditional roles. An exponential increase in global information flows has also generated new risks around data privacy and security. Meanwhile, businesses across sectors are grappling with challenges related to changing customer expectations, cultural transformation, outdated regulation and skill shortages, among others.

The World Economic Forum is committed to helping leaders understand the implications of digitalization and supporting them on the journey to shape better opportunities for business and society. The Digital Transformation Initiative (DTI) is a project launched by the World Economic Forum in 2015 to serve as the focal point for new opportunities and themes arising from the latest developments in the digitalization of business and society. It supports the Forum’s broader activity around the theme of the Fourth Industrial Revolution.

In 2015, the DTI project analysed the impact of digital transformation on six key industries – automotive, consumer goods, electricity, healthcare, logistics and media, and on three cross-industry topics – digital consumption, digital enterprise and societal implications. In 2016, the initiative was extended to cover seven additional industries, including mining and metals, and two new cross-industry themes: platform economy, and societal value and policy imperatives. Through its broad focus, DTI has driven engagement on some of the most pressing topics facing industries and businesses today, and provided business and policy leaders with an informed perspective on how to take action.

The report was prepared in collaboration with Accenture, whom we would like to thank for their support. We also extend our gratitude to the members of the World Economic Forum’s Mining and Metals DTI Advisory Group and the more than 40 experts from industry partners, government and academia who were involved in shaping the insights and recommendations of this project.

We are confident the findings will contribute to improving the state of the world through digital transformation, both for business and society.
INTRODUCTION TO THE DIGITAL TRANSFORMATION INITIATIVE (DTI)

In a world where game-changing innovation has become the norm, DTI provides a unique insight into the impact of technology on business and society over the next decade.

The past 12 months have brought a series of exciting technological breakthroughs. Self-driving Tesla cars can now be seen on the road; Uber is testing autonomous taxis in Pittsburgh; Google DeepMind’s Alpha Go demonstrated a leap forward in artificial intelligence with a famous victory at the board game Go; and augmented reality hit the mainstream with the success of Pokémon Go. Game-changing innovation has become the norm.

Digital innovation is reshaping industries by disrupting existing business and operating models. But it is also having a profound impact on society, presenting a series of opportunities and challenges for businesses and policy-makers.

The Digital Transformation Initiative (DTI) is a project launched by the World Economic Forum in 2015 to serve as the focal point for new opportunities and themes arising from the latest developments in the digitalization of business and society. Over the past two years, DTI has analysed the impact of digital transformation across 13 industries and five cross-industry themes. We have also developed a unique value-at-stake framework to support a consistent approach to measuring the impact of technology on business and wider society. An overview of this framework is included on the next slide.

Our goal is for this framework to provide an evidence base and common language for public-private collaboration focused on ensuring that the benefits of digital transformation are fairly and widely shared.
DTI: A NEW FRAMEWORK FOR PRIVATE-PUBLIC COLLABORATION

Our unique economic framework helps business leaders, regulators and policy-makers unlock the $100 trillion of value that we estimate digitalization across all industries could generate over the next decade.

- We have developed a unique economic framework that aims to quantify the impact of digital transformation on industry and broader society.
- Our framework is new and will be iterated further over the next year, but it can already be applied at all levels of government and business, helping stakeholders make the right decisions to deliver the full potential of digital transformation.
- It provides a consistent evidence base and library of definitions for digital concepts, supporting a global, multistakeholder dialogue about digitalization and its implications.
- We have achieved proof of concept of the framework at an industry level (11 industries) and successfully piloted its application at a national / state level (in Denmark, India, the United Kingdom and the Indian state of Telangana).
A challenging outlook looks set to become the ‘new normal’. To thrive in this environment, mining and metals firms must seize the opportunities offered by digital technologies.

Five years after this century’s commodity boom peaked in 2011, many segments within the global mining and metals industry continue to face severe challenges. These include:

• Weak global demand
• Persistent excess capacity
• Increasing customer requirements
• Trade flow disruptions
• Growing resource nationalism and regulation
• Widening workforce skill gaps
• Declining resource access and quality

These challenges have caused severe price declines, increased volatility and low utilization levels that, in turn, have led to plunging profits and cash flows, steep cutbacks in capital investment, portfolio restructurings and weakened balance sheets, and share price collapses. There has also been widespread management turnover, and increased worker and societal unrest.

As these conditions persist and even intensify, there is a growing sense among industry participants that they are facing not the cyclical correction preceding a boom, but rather the onset of a fundamentally new and more permanent set of conditions. Indeed, there are strong reasons to expect that these conditions represent a ‘new normal’.

Download White Paper
Macroeconomic, industry, geopolitical, demographic, regulatory and societal trends are impacting the mining and metals industries.
TECHNOLOGY ADOPTION TO ADDRESS INDUSTRY-SPECIFIC CHALLENGES

Historically, mining and metals companies have been technology innovators and leaders (e.g. sensors) in some areas, and followers and late adopters in others (e.g. integrated digital platforms). The result is that, compared to other industries, especially customer-facing ones, the mining and metals sector is considered to have lower levels of digital utilization.

**Monitoring and automating heavy fixed assets**

The mining and metals industry has very costly fixed-asset operations and machinery, whose maintenance and depreciable life can impact output, operating and capital expenditures. Sensors on or near hardware connected to diggers, trucks, crushers, conveyors, plants and tailings treatment can gather and share information about machinery, processes and environmental conditions. For most production or processing plants, digitally enabled automation means humans are now decision-makers and operation controllers, while machines do the physical work.

**Connecting dispersed, diverse and remote operations**

As industry players have grown larger and more global, the first wave of digitalization connected disparate operations and aligned corporate processes and reporting via enterprise resource platforms (ERPs). In mining especially, worldwide consolidation has meant heavy investment in digital infrastructure to connect sometimes remote locations to telephone, internet and video networks.

**Empowering and protecting workers**

As the target workforce for the mining and metals industries has become smaller, more specialized and more expensive, digital tools have enabled management and local operations workers to better adjust production and troubleshoot problems. Given the dangerous nature of working conditions on the ground and the risk to the local environment, connected sensors, monitors and alarms have become key tools for preventing and reporting potentially harmful events and conditions.
MINING AND METALS: DIGITAL THEMES AND INITIATIVES

We expect four digital themes to play a crucial role in the digital transformation of mining and metals in the decade to 2025.

**Automation, Robotics and Operational Hardware**
Deploying digitally enabled hardware tools to perform or improve activities that have traditionally been carried out manually or with human-controlled machinery. This theme looks at condition monitoring, predictive forecasting and reliability-centred maintenance, enabled by analytics and robotics.

**Digitally Enabled Workforce**
Linking operations, IT layers and devices or systems that are currently separate. Important technologies include integrated sales and operations planning, asset cybersecurity, information technology (IT) / operational technology (OT) convergence, smart sensors, and advanced track-and-trace technologies.

**Integrated Enterprise, Platforms and Ecosystems**
Leveraging algorithms and artificial intelligence to process data from sources within and beyond the traditional value chain, in order to provide real-time decision support and future projections. Important technologies include exploration, field development planning and asset performance monitoring.

**Next-Generation Analytics and Decision Support**
Using connected mobility, and virtual and augmented reality to empower field, remote and centralized workers in real time. Improvements in connectivity and other breakthroughs, such as wearable technologies, the Internet of Things (IoT), virtual reality (VR) and augmented reality (AR) have opened up further innovation in this field.

Total value at stake

<table>
<thead>
<tr>
<th>Industry</th>
<th>Society</th>
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<tbody>
<tr>
<td><strong>Automation, Robotics and Operational Hardware</strong></td>
<td><strong>Digitally Enabled Workforce</strong></td>
</tr>
<tr>
<td>$90 billion</td>
<td>$162 billion</td>
</tr>
<tr>
<td>$30 billion</td>
<td>$7 billion</td>
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</tbody>
</table>

Total value at stake

<table>
<thead>
<tr>
<th>Industry</th>
<th>Society</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total value at stake</strong></td>
<td></td>
</tr>
<tr>
<td><strong>$90 billion</strong></td>
<td><strong>$30 billion</strong></td>
</tr>
</tbody>
</table>
Within each theme, digital initiatives define the technologies that are expected to have a significant impact on the industry’s value chain, its workforce, adjacent industries, the environment and wider society.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Initiatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation, Robotics and Operational Hardware</td>
<td>Autonomous Operations and Robotics</td>
</tr>
<tr>
<td></td>
<td>3D Printing</td>
</tr>
<tr>
<td></td>
<td>Smart Sensors</td>
</tr>
<tr>
<td>Digitally Enabled Workforce</td>
<td>Connected Worker</td>
</tr>
<tr>
<td></td>
<td>Remote Operations Centre</td>
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<tr>
<td>Integrated Enterprise, Platforms and Ecosystems</td>
<td>IT/OT Convergence</td>
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<td></td>
<td>Asset Cybersecurity</td>
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<td></td>
<td>Integrated Sourcing, Data Exchange, Commerce</td>
</tr>
<tr>
<td>Next-Generation Analytics and Decision Support</td>
<td>Advanced Analytics and Simulation Modelling</td>
</tr>
<tr>
<td></td>
<td>Artificial Intelligence</td>
</tr>
</tbody>
</table>

\[1 \text{ Value at stake for these initiatives not calculated independently.}\]
The digitalization of mining and metals could unlock more than $400 billion of value for the industry and society over the next decade. Societal benefits include lower carbon emissions, reduced water consumption and less soil contamination.

Digital transformation in mining and metals has the potential to create approximately three times as much value ($321 billion) for the industry than for wider society ($106 billion). The initiatives that create the largest impact for this industry are Integrated Platforms, Connected Worker and Remote Operations Centre, which are collectively accountable for more than 60% of the value at stake.

### Mining and metals: value at stake for industry and wider society (by digital initiative)

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Potential Business Impact ($ billion)</th>
<th>Potential Societal Impact ($ billion)</th>
<th>Total Value at Stake ($ billion)</th>
<th>Emissions Reduction (million tonnes CO₂)</th>
<th>Net Impact on Jobs (000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Sensors</td>
<td>34</td>
<td>8</td>
<td>42</td>
<td>161</td>
<td>(40)</td>
</tr>
<tr>
<td>Autonomous Operations &amp; Robotics</td>
<td>56</td>
<td>19</td>
<td>75</td>
<td>396</td>
<td>(60)</td>
</tr>
<tr>
<td>3D Printing</td>
<td>--</td>
<td>3</td>
<td>3</td>
<td>35</td>
<td>--</td>
</tr>
<tr>
<td>Connected Worker</td>
<td>85</td>
<td>--</td>
<td>85</td>
<td>--</td>
<td>(201)</td>
</tr>
<tr>
<td>Remote Operations Centre</td>
<td>77</td>
<td>7</td>
<td>84</td>
<td>16</td>
<td>(12)</td>
</tr>
<tr>
<td>Asset Cybersecurity</td>
<td>21</td>
<td>--</td>
<td>21</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Integrated Platforms</td>
<td>37</td>
<td>69</td>
<td>106</td>
<td>--</td>
<td>(5)</td>
</tr>
<tr>
<td>Advanced Analytics</td>
<td>11</td>
<td>--</td>
<td>11</td>
<td>--</td>
<td>(13)</td>
</tr>
<tr>
<td>Total</td>
<td>321</td>
<td>106</td>
<td>427</td>
<td>608</td>
<td>(330)</td>
</tr>
</tbody>
</table>

Source: World Economic Forum / Accenture analysis
Technologies such as robots, 3D printing and smart sensors offer opportunities for mining and metals companies to revolutionize their operations and create significant value.

**Autonomous Operations and Robotics**

A new generation of robots and machinery can perform tasks with a high degree of autonomy, working for extended periods without any human intervention. Operational hardware is also increasingly capable of learning new methods for accomplishing tasks or adapting to changing surroundings. Autonomous machines could create $56 billion of value for the industry through an increase in output. Greater operational efficiency is expected to reduce CO\textsubscript{2} emissions by approximately 400 million tonnes.

**3D Printing**

If it becomes more economical and scalable, 3D printing will be an innovative way for mining companies to source metal and plastic parts. As the technology improves and costs come down, mining and metals companies may consider selling raw products, either as supplies to 3D printing businesses or direct to customers and consumers. The value impact of 3D printing is relatively small. One reason is that, at present, the technology is largely confined to high-cost, low-volume goods in certain industries (e.g. design, aerospace, automotive.)

**Smart Sensors**

Smart sensors collect physical, biological or chemical input data, process it and make decisions based on it. Companies can use smart sensors to get real-time insights into the performance of their infrastructure, derived from data about the physical condition and operational performance of machines. Smart sensors could create approximately $34 billion of value for the industry by reducing energy and maintenance costs and boosting productivity.

Illustrative case studies:
FOCUS ON DIGITALLY ENABLED WORKFORCE: DIGITAL INITIATIVES

Together with remote control centres, digital technologies that empower field workers are set to revolutionize mining and metals operations.

Connected Worker

Connected mobility, VR and AR technologies can be used to empower and monitor field workers. These employees benefit from on-demand, real-time push and pull information and use mobile and wearable technologies (e.g. tablets, smart glasses, watches and vitals trackers) to interact with sensors, robots and other systems around them. These technologies boost worker productivity, contributing up to $85 billion of value for the industry and potentially displacing around 200,000 jobs.

Remote Operations Centre

Remote operations centres (ROCs) are centralized, connected control rooms for mines and metals plants, providing an off-site environment for personnel to collaborate on operations without travelling to the site itself. Thanks to improvements in connectivity, these control rooms can be located almost anywhere in the world. They could generate around $84 billion of value for the industry by reducing the costs associated with having highly specialized staff on site. Reducing on-site personnel could also contribute to saving approximately 250 lives.

Illustrative case studies:
By connecting IT to operational technology and exchanging data throughout the supply chain and beyond, the mining and metals industry could generate significant value for itself and for society.

**IT / OT Convergence**

This digital initiative looks at linking OT and IT layers and devices or systems that are currently separate. IT and OT are coming together via the Internet of Things (IoT), which connects objects to internet infrastructure via embedded computing devices such as radio frequency identification (RFID) chips and sensors. Value at stake for IT / OT convergence has been valued implicitly within other initiatives.

**Integrated Sourcing, Data Exchange, Commerce**

This initiative focuses on leveraging technology to exchange or integrate data – and thus boost collaboration – across multiple steps of the value chain. This could take place across functions within one company or even beyond – including, for instance, key partners such as suppliers and customers. Integrated B2B commerce platforms could unlock $37 billion of value for the industry and $69 billion for metals customers by ‘cutting out the middleman’.

**Asset Cybersecurity**

The scale of cyberattacks by hackers, criminals and governments is unprecedented. Asset cybersecurity is the collection of tools, policies, safeguards, risk management approaches, best practices and technologies that protect the cyberenvironment, and an organization’s or user’s assets within. This initiative could be worth $21 billion to the industry through avoided costs of cyberattacks.
FOCUS ON NEXT-GENERATION ANALYTICS AND DECISION SUPPORT: DIGITAL INITIATIVES

Using algorithms and artificial intelligence to process data can help with real-time decision support and future projections.

Advanced Analytics and Simulation Modelling

Mining and metals companies can use analytics and decision support to make better, faster decisions. Analytics capabilities optimize materials sourcing, enhance predictive maintenance to increase machine uptime, or adjust processes to create tailored products and services for the customer. Across mining and metals, advanced analytics can add value to plant and maintenance operations by identifying operational bottlenecks or waste patterns. We estimate it could generate $11 billion of value for the industry.

Artificial Intelligence (AI)

To support humans in the processes of problem solving, machines must analyse massive amounts of data from various input sources such as mining hardware, worker equipment and databases. In this way, AI helps decision-makers make more informed choices, optimize yields and minimize environmentally harmful inputs. AI should boost efficiency through improved operational throughput, as removing bottlenecks is done intelligently on an ongoing basis. This initiative has not been valued due to the nascent and uncertain nature of AI within mining and metals.

Illustrative case studies:

Mira Geoscience
GOLDCORP
Here are just three of the more than 15 case studies that can be found in our white paper on digital transformation in the mining and metals industry.

**Metso:**
*Using visualization sensors in metal production for bubble monitoring*

Metso is using visual sensors to enable clients to monitor the bubbles in their steel production. The amount of air and the size of the bubbles in a steel furnace affects the quality of the final product. However, the intense heat makes it hard to take readings from the molten metal. Visual sensors, coupled with heat sensors, can scan the surface of the molten metal and quickly assess the quality of the steel and automatically identify any adjustments to the process that are needed. The result: a higher-quality, more consistent product.

**DAQRI:**
*Making helmets smart and improving worker safety*

DAQRI is an American AR company founded in 2010. Its smart helmets enhance human capabilities across industries by seamlessly connecting users to their work environment. The helmet, which complies with safety standards, includes a main logic board with twice the processing speed of a normal computer; a camera for passive thermal monitoring of industrial equipment; an audio array board for advanced communications; 13MP HD cameras; an industrial infrared system; and an inertial measurement unit. DAQRI has also developed an operating system specifically designed and optimized for wearable computing.

**Teck Resources:**
*Using real-time data feeds to increase transparency*

Canada’s largest diversified mining company, Teck Resources has used digital tools to build awareness and trust around the environmental impact of its operations. By using sensors with frequent data feeds in watershed management, the company has been able to find slight variations it was unable to identify through daily sampling techniques, while simultaneously sharing hourly results on dust particles and water quality near its sites at Carmen de Andacollo, Chile, and Elk Valley, Canada. This helps the local communities understand its impact and feel safe, and allows analysis and reporting by government.
The digital revolution will intensify and accelerate several of the key challenges facing the global mining and metals industry. Yet at the same time, digital technologies can provide mining and metals companies with tools to mitigate and counter these challenges.

<table>
<thead>
<tr>
<th>INDUSTRY CHALLENGE</th>
<th>INTENSIFIED / ACCELERATED BY DIGITAL</th>
<th>POTENTIAL INDUSTRY DIGITAL RESPONSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEAK GLOBAL DEMAND</td>
<td>• Slower demand growth due to digitally enabled consumer sharing models (e.g. Uber), ‘products as services’, improved supply-chain efficiencies, and the circular economy.</td>
<td>• Improved products and value-chain efficiencies to win share from other materials or value chains.</td>
</tr>
<tr>
<td>PERSISTENT EXCESS CAPACITY</td>
<td>• Digital may improve the viability of weak assets and operations, thereby prolonging excess capacity.</td>
<td>• New business models based on value-chain disruption.</td>
</tr>
<tr>
<td>INCREASING CUSTOMER REQUIREMENTS</td>
<td>• Huge disruptions emanating from end-user markets will flow back through the value chain, creating new requirements.</td>
<td>• Faster product innovation, new forms of customer service, and closer customer collaboration.</td>
</tr>
<tr>
<td>TRADE FLOW DISRUPTIONS</td>
<td>• Not apparent.</td>
<td>• Digital tools to increase agility and mitigate impacts of volatility on operations.</td>
</tr>
<tr>
<td>DECLINING RESOURCE ACCESS AND QUALITY</td>
<td>• Not apparent.</td>
<td>• Digital technologies for locating and optimally extracting and processing ores.</td>
</tr>
<tr>
<td>INCREASING RESOURCE NATIONALISM AND REGULATION</td>
<td>• Digital enables greater visibility and monitoring of operations and societal impacts.</td>
<td>• Tools to improve stakeholder engagement and reporting.</td>
</tr>
<tr>
<td>WORKFORCE SKILLS</td>
<td>• Gap between existing workforce skills and increasing technical requirements, especially in emerging economies.</td>
<td>• Digitally enabled workforce.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Automation, robotics, and hardware.</td>
</tr>
</tbody>
</table>
RECOMMENDATIONS FOR INDUSTRY LEADERS

The full value of digitalization will only be unlocked through collaboration between mining and metals companies, communities and policy-makers.

Align business to use innovation in operations and innovate on the side
Build a focused digital strategy and align it with your business model, processes and organization, to encourage digital usage and experimentation.

Look outside of your current business
Differentiate products from commodities; move into more value-added or synergistic parts of the value chain; draw deeper insights from customer data.

Improve data access and relevance
Focus on getting real, applicable insights from data and sharing them clearly and effectively with the right levels of the organization.

Engage and train tomorrow’s digital workforce
Young workers need to be actively pulled into the industry and those populations that do not have the digital knowledge, such as in the developing world or ageing workers, must be trained for digital work internally or through practical educational partnerships.

Invest in alternative benefits, not just jobs
Invest now in finding other ways to work with and compensate local stakeholders for the responsible use of their resources. Initiatives could include developing infrastructure, supporting education or building expertise.

Forge new partnerships and strengthen existing ones
Improving active and open partnerships is the foundation for best-in-class digitalization, stronger integration with local stakeholders, and even new models of operation and ownership of mining and metals fixed assets.
RECOMMENDATIONS FOR POLICY-MAKERS

The full value of digitalization will only be unlocked through collaboration between mining and metals companies, communities and policy-makers.

Define effective digital standardization
The wider community should help define a set of data ownership and format standards that will encourage interoperability and the sharing of information across all elements of the digital ecosystem, while maintaining the levels of privacy and security that are needed.

Prioritize KPIs and aggregate data
Though there are a number of possible key performance indicators (KPIs) that have been used to tie mining and metals to local development, there is no clear standard or repository that can give a full causal view or suggest how to best invest for industry and society.

Improve transparency and traceability
Digital can be a tool to provide better production and supply chain monitoring, while simultaneously building trust. It can also be a way to establish and promote better use of existing data, from historic exploration data to establishing and maintaining legitimate property rights.
Over the past two years, DTI research has focused on understanding the impact of digital transformation in 13 industries and drawing insights from the cross-industry themes that came out of that analysis.

We have covered five cross-industry themes. **Digital Consumption** explains how the rapidly changing expectations of digital customers are forcing enterprises to reinvent themselves. **Digital Enterprise** looks at how companies can respond by rethinking every aspect of their business. **Platform Economy** focuses on the immense impact of one type of digitally enabled business model – B2B platforms. The adoption of new digital business and operating models is having a profound impact on society, a theme we analyse in **Societal Implications**. We then introduce our quantitative analysis of the impact of digitalization on business and wider society in our final cross-industry theme, **Societal Value and Policy Imperatives**.

Our industry deep dives have covered 13 industries: Automotive; Aviation, Travel and Tourism; Chemistry and Advanced Materials; Consumer; Electricity; Logistics; Media; Mining and Metals; Oil and Gas; Professional Services; Retail and Telecommunications.

White papers, SlideShares, articles, an overall executive summary for the DTI project, and a library of video interviews can be found on our website.
ACKNOWLEDGEMENTS

The World Economic Forum would like to acknowledge and extend its sincere gratitude to a broad community of contributors across Partner companies, technology start-ups, academicians and experts.

**Participating Organizations**

- Alcoa
- Anglo American
- Antofagasta Minerals
- BlueOak
- Centre for Excellence in Mining Innovation
- Clareo
- Columbia Center on Sustainable Investment
- Cornell University
- DAQRI
- Duke University
- Eurasian Resources Group
- Freeport-McMoRan
- Gerdau
- Goldcorp
- Harvard University
- IHS Automotive
- International Council on Mining & Metals
- Klöckner
- mjunction Services
- Newmont Mining Corporation
- Nucor Corporation
- Platform Strategy Labs
- Prospectors & Developers Association of Canada (PDAC)
- RESOLVE
- Rio Tinto
- SAP
- Severstal
- Stratasys
- Tata Steel
- Teck Resources
- United Nations Development Programme
- United Nations Economic Commission for Africa
- United States Steel Corporation
- University of Queensland
- Vale International
- World Steel Association

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