**An American Standard for Deep Seabed Nodule Industry**

**Written Testimony Before the House Committee on Space, Science and Technology**

**Hearing on "Beneath the Waves: The Science and Technology of Deep-Sea Mining"**

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Chairman Babin, Ranking Member Lofgren, and distinguished Members of the Committee,

Thank you for the opportunity to appear before you today.

We stand at the dawn of a new American offshore minerals industry that has been more than half a century in the making. I believe this dawn is rather unusual as I am hard-pressed to think of another resource industry that has been preceded by decades of environmental research and regulatory development before a single ton of ore was commercially recovered.

The technology to bring offshore minerals from the abyss to the surface—while by no means trivial—was never the hold up. Indeed, several U.S. based consortia conducted successful pilots of deep-sea mining systems already back in the 1970s.

The 1970s were also marked by a strong bipartisan consensus that delivered several hallmark environmental laws including the Clean Air Act, Clean Water Act and Endangered Species Act. Protecting the environment and not repeating the mistakes made in extractive industries on land were top of the agenda. This was the context that set the offshore minerals industry on its unusual course.

My objective today is to survey the progress that has been made in deep sea research and technology development since the 1970s. Because of the heightened sensitivity around potential impacts on the marine environment, deep sea research has been extensive and a key driver of how technology has been developed. Offshore minerals is not an industry racing ahead of science. It is an industry informed by science.

To understand why this matters now, let's begin with the type of deep-sea mineral resource where the start of commercial recovery is imminent: polymetallic nodules.

**1. Three Mines in One—For Centuries**

In the high seas in between Hawaii and Mexico, in an area known as the Clarion-Clipperton Zone or CCZ, the abyssal seafloor hosts vast fields of polymetallic nodules. These potato-sized discrete rocks contain four critical metals in a single rock: copper, nickel, cobalt, and manganese.

All four metals are on the U.S. Critical Minerals List. American dependency on foreign supply of primary metal units is near total – 100% for nickel, 100% for cobalt, 100% for manganese, and 46% for copper (USGS 2025). All four metals are critical inputs into sectors viewed as strategic for America, including defense, AI, energy and marine industrial base.

Compared to other domestic prospects of the same metals, the CCZ nodule resource is an outlier:

- Combination of metals: On land, it typically takes three separate mines, across multiple jurisdictions, to produce this combination of metals. In the CCZ, these four metals co-exist in a single resource and can be simply and safely lifted from the deep seabed with a mobile offshore nodule collection system and without any permanent infrastructure on the seafloor.
- The content of each metal: At 1.4% nickel, 1.1% copper, 0.2% cobalt, and nearly 30% manganese, CCZ nodules contain more of each metal than almost all other domestic metal projects.
- Size of the resource: The CCZ is estimated to host 20 billion tonnes of nodules—containing more nickel, cobalt, and manganese than all known terrestrial reserves combined globally, not just domestically (Hein, 2020) (Morgan 1999) (International Seabed Authority (ISA) 2010). To give you a sense of scale, at current levels of U.S. consumption, one billion tonnes of nodules contains the equivalent of 300 years of manganese, 200 years of cobalt, 100 years of nickel, as well as half a decade of copper (U.S. Geological Survey (USGS) 2024). In our exploration areas, TMC USA alone has already defined a 1.6 billion tonne resource. We are one of at least six other American companies.
- Habitat abundance: From a conservation perspective, sourcing metals from nodules on the abyssal plains makes perfect sense. Abyssal plains are the most common habitat on Earth, covering over 70% of the global seafloor, with far lower levels of biodiversity than the unique forested ecosystems mined today which make up a very small proportion of available habitat.

This resource has the potential to not just reverse American dependency on foreign / adversarial sources of critical minerals but turn America into a global powerhouse and net exporter of base metals, a role America enjoyed between the 1880s and 1970s. It is also an opportunity to restore a leadership position in an industry pioneered by Americans and to set the bar for how a new offshore industry should be developed in the 21st century.

## 2. The Original American Pioneers

The Brits may have discovered polymetallic nodules in the CCZ some 150 years ago, but it was an American geologist, John Mero, who in the 1960s imagined turning vast fields of polymetallic nodules into a new source of base metals for the United States (Mero 1965). It was US-based consortia who successfully tested nodule mining technology in the 1970s (NOAA 1981a). It was the U.S. Navy that was the primary origin for the development of deep-sea autonomous underwater vehicles (AUVs), with key advances from leading research institutions: Woods Hole Oceanographic Institution's Autonomous Benthic Explorer (ABE) was one of the first widely-used scientific AUVs; MIT delivered key breakthroughs in GPS-independent underwater navigation; while Scripps' work enabled long-range applications (Bellingham, et al. 2016).These were the times when the United States put a man on the moon and built technology to recover polymetallic nodules from the abyss in the middle of the Pacific Ocean.

Successfully tested technology concepts involved large machines that moved on the seafloor using tracks or Archimedes-screws. Because nodules are discrete rocks that sit on top of fluffy seafloor mud, unattached to the seafloor, no drilling or blasting equipment was required to break the seafloor. Nodules were simply picked up either hydraulically using a Coanda effect or mechanically raked using tines. Picked up nodules along with any seafloor mud were pumped into a long steel pipe connecting the mining vehicle on the seafloor to the ship on the surface. Unwanted mud was separated from the nodules and discharged overboard.

This type of operation understandably raised several environmental concerns: what will happen to the seafloor ecosystem when nodules are removed? how much mud will be suspended at the seafloor? how far will the resulting seafloor (benthic) plumes travel and how will they impact benthic life? how much mud will be lifted to the surface and how will the resulting surface plumes impact marine life (and fisheries) once they are discharged over board?

Alongside pioneers of industry, the National Oceanic and Atmospheric Administration (NOAA) pioneered assessment of environmental impacts. Under its Deep Ocean Mining Environmental Studies (DOMES) program running from 1975 to 1981, NOAA completed several environmental research cruises and developed a Programmatic Environmental Impact Statement (PEIS) for the DOMES area that included the CCZ. Twenty-five people across various government agencies and universities were listed as co-authors of this sprawling 300+page volume that was shared widely—with key Senate and House Committees, 40 federal departments and agencies, 10 states, 9 embassies of foreign countries, 57 special interest groups and 359 individuals. The development of this volume was a public affair with 28 public meetings and workshops held over a period of 6 years and involving Federal and State government, academia, environmental and public groups, industry and private individuals (NOAA 1981a).

NOAA also produced a Technical Guidance Document to inform nodule explorers' efforts to collect environmental information for site-specific Environmental Impact Assessments (NOAA 1981b) and went on to develop a total of five such site-specific Environmental Impact Statements as part of its process to grant exploration licenses in the CCZ (NOAA 1984abcd, 1994). Between 1981 and 1995, NOAA regularly reported on Deep Seabed Mining to Congress, producing a total of 7 reports (NOAA 1981-1995). In these reports, NOAA advised that the agency's 1975-80 DOMES Project had addressed most environmental questions (pending verification during monitoring of further at-sea mining system tests) and its work in the 1990s was focused on the last outstanding issue—determining the biological effects of the increased sedimentation on the seafloor (i.e., seafloor plumes) that would result from deep seabed mining operations.

To address the issue of seafloor plumes, NOAA developed a Benthic Impact Experiment program and, after the first unsuccessful device, commissioned an American company Sound Ocean Systems Inc (now Okeanus) to build a better machine to simulate benthic disturbance. The machine came to be known as the Disturber 2.0, and as the name suggests was designed to maximize sediment disturbance to study worst case scenarios. It was used not just by NOAA but was borrowed—along with the NOAA team for consistency of use—by several other governments around the world including Japan, India and a group of Eastern European countries to conduct disturbance experiments of their own (NOAA 1995).

On the regulatory side, the U.S. Congress passed the Deep Seabed Hard Minerals Resources Act in 1980 (DSHMRA). The Act created a legal framework to enable U.S. citizens to explore and recover seabed minerals in the high seas and authorized NOAA to develop implementing regulations. NOAA delivered implementing regulations for exploration licenses in 1981 (NOAA 1981c) and proceeded to issue four exploration licenses, known as USA-1, USA-2, USA-3 and USA-4. NOAA then invested over six years in the development of implementing regulations for commercial recovery permits, with multiple iterations and several rounds of public hearings and comments. Final regulations came into force in 1989 (NOAA 1989).

It is worth recalling again that the 1970s was the decade of hallmark statutes on environmental protection: the National Environmental Policy Act of 1970, Clean Water Act of 1972, Marine Mammal Protection Act of 1972, Endangered Species Act of 1973 and Magnuson Fishery Conservation and Management Act of 1976, all explicitly referenced in DSHMRA and its implementing regulations. By 1989, America had developed a robust regulatory regime for deep seabed mining in the high seas that was fully consistent with international law, commercially viable, and environmentally responsible.

### 3. Developing the Environmental Baseline in the 21st Century

For reasons outside the scope of this testimony (House Natural Resources Subcommittee on Oversight and Investigations, 2025), since the late 1990s and until last April's Executive Order 14285 designed to unleash American offshore minerals industry, exploration activity in

the CCZ continued under the international regulatory regime pursuant to the United Nations Convention on the Law of the Seas (UNCLOS), a convention the United States is not party to. Driven by a precautionary approach, more than 40% of the CCZ was set aside into protected areas, ahead of the current internationally agreed target to protect 30% of the world's oceans by 2030. Over $2 billion has been invested into deep-sea mineral exploration, with over 300 research cruises completed and over 9,000 days spent on site in the high seas. A quick search of Google Scholar will tell you that almost 200,000 articles have been published on polymetallic nodules in general and over 50,000 articles specifically on polymetallic nodules in the Eastern CCZ, the area where we at TMC USA plan to become the first American company to be allowed to commercially recover polymetallic nodules.

Our plan is underpinned by 15 years and over $700 million investment in exploration, environmental research, and technology development. Following in NOAA's footsteps and in collaboration with more than 20 universities, research institutes, and expert industry contractors, we completed an ambitious environmental research program spanning 27 offshore campaigns. San Diego was the home base for our offshore operations and many of the leading experts contributing to our program are based in the United States (e.g., CSA Ocean Sciences Inc, Eckerd College, Florida State University, Texas A&M University, University of Hawaii, University of Maryland, MIT).

We have assembled the largest deep-sea environmental dataset in the industry—over one petabyte in size—covering seafloor-to-surface biodiversity, sediment dynamics, plume behavior, oceanography, and ecosystem function. All researchers involved in our environmental program are free to publish their findings in peer-reviewed journals—many already have. Most of our environmental data is publicly available. Our data accounts for almost half of all biological records for the entire CCZ (OBIS 2026). A dozen peer-reviewed papers using our data have already been published, with hundreds more expected in the coming years as researchers engage further with our existing data and we collect more during future monitoring of commercial operations (The Metals Company 2026).

This data is contributing to the global understanding of deep-sea ecosystems in the CCZ. Just this week a new species discovery made during one of our offshore campaigns was ranked among the most significant achievements in global marine taxonomy in 2025 (UK National Oceanography Centre 2026).

While we get very excited about advancing humanity's understanding of deep-sea ecosystems—we have nine PhDs in marine biology and oceanography on our team—the primary objective of our research is reduction and management of environmental risks. We need to know enough to be able to assess and manage risks, and to develop technology that effectively reduces these risks.

**4. When Environmental Impacts Drive Technology Development**

The difference between legacy 1970s systems and the technology we developed together with our offshore partner Allseas—based on the insights from our environmental program—is not

incremental. Here are just three examples of developments that drive our impacts on the marine environment:

- Depth of seafloor disturbance: In the 1970s, collection systems left behind deep tracks—up to 80 centimeters deep (Jones, et al. 2025). Decades later, these tracks are still intact and clearly visible on the seafloor. In contrast, our tracked seafloor nodule collector disturbs just the top 5 centimeters, leaving behind barely perceptible ripples in the sediment. Through buoyancy control, we have significantly reduced the collector vehicle's weight at the seafloor, enabling it to move lightly across the seabed.
- Size and control of seafloor plumes: Deep-sinking machines of the 1970s displaced and mobilized large volumes of sediment over which they had limited control. Today, the total volume of sediment displaced by our tracks and entrained through nodule pick up is small in comparison. While we still rely on Coanda effect for hydraulic pickup of nodules, modern sensors and articulation of pickup heads allow us to focus our jets of seawater much more precisely and to lift nodules while minimizing the entrainment of underlying sediment. The sediment that does end up inside the nodule collector is separated from the nodules and discharged at the seabed using special diffuser systems designed to slow discharge and promote the formation of a fast-settling gravity flow, keeping sediment movement within a limited footprint. Discharged sediment resettles within tens to hundreds of meters and is all but undetectable after one kilometer.
- Size and placement of plumes in the water column: In the 1970s, the sediment lifted to the surface was simply discharged overboard into the most productive surface layers of the ocean. We have adopted a different sediment management philosophy: we minimize the intake and maximize separation from nodules at the seafloor, and any residual sediment is discharged not at the surface but at depth, where the risk of interacting with the productive surface layers and commercial fisheries is minimized. Our nodule collector can separate most entrained sediment within the collector itself—returning roughly 95 percent directly to the seafloor in a controlled and localized manner using specially designed diffusers. The approximately five percent of sediment that escapes separation at the seafloor and travels alongside nodules to the surface is returned to a depth of 2,000 meters, specifically chosen, following the advice of leading academics, to minimize interaction with the food webs of fisheries (The Metals Company 2025).

The impacts of our design choices described above are based on field testing and monitoring. In 2022, we conducted integrated nodule collection testing in partnership with Allseas and almost 100 scientists from partnering universities and research organizations who monitored our operations from a separate vessel. Over 50 assets were deployed on the seabed and throughout the water-column—including moorings, current meters, and plume monitoring systems—to measure sediment behavior and validate our models.

We then returned to the test site 12 months later and observed encouraging signs: following a test using our new generation of technology, the ecosystem was not only recovering, but it

was doing so much quicker than had been observed in the CCZ in the four decades after the tests using the 1970s technology. Within just 12 months, sediment-dwelling macrofauna and foraminifera in our test area had rebounded to roughly 30% of pre-disturbance abundance and 50% of diversity. Microbial communities, which make up around 60% of resident biomass, showed no significant change in any disturbance area, while impacts on other organisms were limited to collector tracks and centimeter-scale sedimentation within 10 meters. No measurable effects were found beyond 100 meters from the mined areas. (O'Malley, et al. 2025). We intend to continue monitoring the test site and expect this trajectory of recovery to continue to improve.

Our technology testing and monitoring showed that nodule collection technology has advanced significantly since the pioneering trials of the 1970s, progress that must be reflected in today's debate if we are to credibly assess this industry's environmental impacts (Ingels, et al. 2026). These technological advances are further supported by an Adaptive Management System (AMS) that integrates environmental and operational data across the production system and that we intend to use for the environmental management of future operations. The core pillar of our AMS is a Digital Twin that we developed in partnership with Kongsberg Digital and which enables visualization of the operating environment and testing of scenarios to ensure operations remain within environmental thresholds (The Metals Company 2023). Elements of this integrated system are designed to carry forward into commercial operations, providing ongoing transparency and enabling adaptive management throughout the life of the project.

Innovation in our industry has been largely driven by the need to minimize our future impacts on the marine environment, and I would argue a great deal has been accomplished in the last 15 years (The Metals Company 2025). The big milestone before the start of commercial recovery is the NEPA EIS process managed by NOAA.

**5. Innovating Above the Waves**

Although the focus of this hearing is science and technology beneath the waves, it is important to mention that the polymetallic nodule resource can enable game-changing breakthroughs above the waves when nodules are processed and refined into metal onshore.

Unlike many terrestrial ores, polymetallic nodules do not contain toxic levels of hazardous elements and, as a result, all of the nodule mass can be turned into products with near zero solid waste. This is revolutionary because most terrestrial mining and processing businesses are effectively waste management companies—they process large volumes of material to extract relatively small amounts of payable metals, generating significant waste and tailings that require environmentally responsible disposal due to their toxic contents. Few people want these waste management facilities in their backyards, and reports show many such facilities are in a precarious condition and liable to fail (World Mine Tailings Failures 2026).

Zero solid waste was one of our key objectives when developing technology for processing and refining nodules into sellable products. Through extensive testing—at bench, pilot, and industrial scale—we have now proven we can get very close.

Another area where we believe America can lead above the waves is an AI and software-first approach to building and operating domestic processing and refining facilities. We believe we can set a new standard for metallurgy in the 21st century and create industrial jobs that Americans would be excited to do—in an industry still remembered for its Dickensian working conditions. The talent and even experience is already here. This is an area where we are already working with our American partner Mariana Minerals to help modernize one of the world's oldest industries and bring new domestic processing capacity online faster, safer, and more cost-effectively.

When assessed as an integrated system—from resource recovery from the seafloor to refined metals—polymetallic nodules offer America a fundamentally different model for producing critical minerals.

**6. Conclusion: Renewed American Leadership**

Half-a-century ago, Americans pioneered the concept of a new offshore minerals industry, developed a strong foundation for assessing environmental impacts and put in place a robust regulatory regime that to this day has no analogues in other jurisdictions. In the decades that followed, American deep-sea scientists continued to contribute to the rapidly growing body of deep sea research. Building on these developments, last April's Executive Order aimed to unleash offshore minerals and has already attracted a dozen new applications to NOAA for new exploration licenses and commercial recovery permits. In TMC USA, America gained not just another new applicant but a leading nodule project developer with proven offshore and onshore technology, the only completed offshore environmental impact assessment program, and a project development approach that relies on strong partnerships and developing ecosystems that will benefit the American industry as whole.

**No other country today has a better scientific, regulatory, and technological basis to oversee the start of a new offshore industry—an industry that can deliver a multi-generational domestic and global supply of several critical minerals, enabling the United States to eliminate foreign dependencies and re-emerge as a global mineral powerhouse.** Decades of deep-sea research and a new generation of technologies are here to enable environmental transparency and accountability: they can help make sure the impacts on the receiving environment are understood, reasonably reduced, continuously monitored and tightly managed. The United States has the opportunity to set the American standard for how deep seabed nodules are mined and turned into reuseable metals to fuel our future. All of us at TMC USA look forward to being part of this process.

Thank you.

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