Facing the Abyss

The Future of Deep Sea Mining

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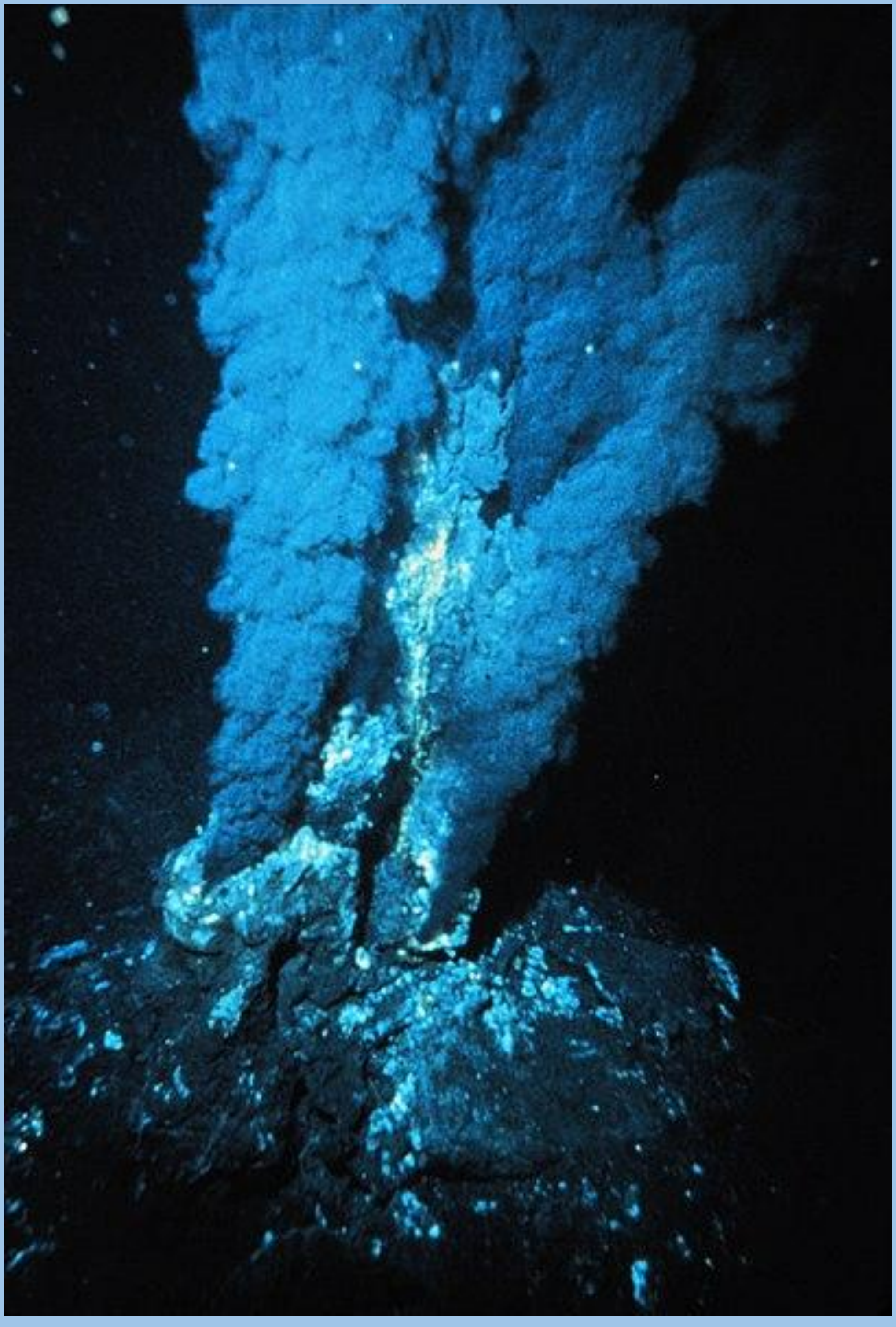


Hydrothermal Vent in the Mid-Atlantic Ridge.
Courtesy: OAR/National Undersea Research Program (NURP) | NOAA

Executive Summary

With metal prices rising, traditional resources being pushed to their limit and technology leaping forward, radical frontiers in the world of mining are beginning to be breached. Accordingly, deep sea mining (DSM) has experienced a resurgence of interest. Unsurprisingly, the prospect of mining in unexplored and biologically unique extreme environments has been met with consternation in many environmental and academic circles. Yet with trends in demand and metal prices expected to continue to rise many concede that the prospect of DSM is now an inevitability. The question has become "when" not "if" and, for the first time in history, commercial activity is scheduled to begin off the coast of Papua New Guinea in 2019. In this review we apply a systems thinking approach to map the underlying drivers, the various players and where best the system might be leveraged to ensure a responsibly governed future for this new industry.

Our Research Methodology

The research team approached the system through the lens of the largest actors for each major driver:

- **Industry Actors** - mining companies, consultants, and industry research firms
- **Public Sphere/Governance Actors**- the United Nations, Sovereign governments, the media, NGOs, and the public
- **Biodiversity Actors**- scientists, researchers, conservationists, and educators

We interviewed representatives from each of the 3 areas except industry. We instead gained industry perspective via press releases, public documents, and existing media interviews. We conducted internal economic and ecological data reviews, using industry, governmental, and academic data - some of which is shared via the visual map. We also conducted a thorough review of the academic literature and select key media.

The Systems Challenge

With deep sea mining set to begin in the next year, the question remains: will it become a sustainable resource of some of the world's rarest minerals, or another example of a human socio-technical system that irreversibly damages Earth's largest environment for generations to come?

The key gaps in the system we identified were:

- Deep sea mining is a highly complex system with many uncertainties
- Deep sea mining is a newly emerging system and is thus in flux
- Existing actors in the system have become entrenched, and strong power dynamics make change difficult
- Feedback loops in the system operate at different scales and speeds

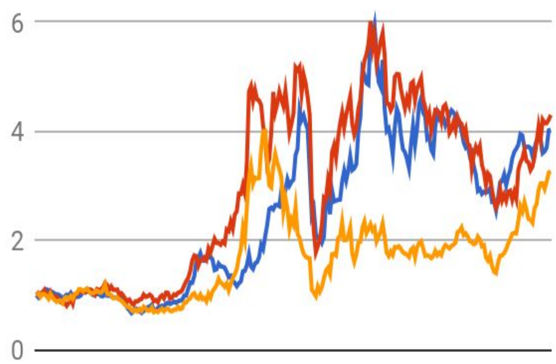
Technical & Economic Overview

The Economic Situation

Over the last century the price of mineral commodities has risen steadily, driven by the growth in global consumption. The advance of consumer electronics since the turn of the millenium has particularly accelerated this trend. However, now terrestrial reserves of elements such as copper and cobalt are struggling to meet demand and there are additional concerns about the security of supplies of technologically vital "rare earth metals". Consequently, after a chequered history, marked with bestselling novels, espionage, speculation bubbles, and with leaps in technological progress clearing a path, the world of economically viable deep sea mining (DSM) appears to be here.

"deep marine mineral exploration is set to become a global industry"

- Dr. Chris Yeates, CSIRO Geologist.



(top left) Changes in copper (red), zinc (yellow) and tin (blue) prices relative to 1998 prices and the number of DSM exploration contracts awarded by the UN (top right), both 1998-2018. Pictured: Mining equipment of *Nautilus Minerals Inc*. Courtesy: *Nautilus Minerals Inc*.

Mining & Minerals

The methods required for deep sea mining involve extreme technical difficulties and variable environmental impacts.

- Mining prospects are centred around three mineral formations found across the world's oceans and at various depths: ***cobalt-rich crusts***, ***hydrothermal vents*** (HTV) and ***polymetallic nodules***
- extraction methods range from intensive strip mining to passive nodule collection.
- Seafloor work is heavily reliant on robotics and autonomous vehicles
- Material waste or *"tailings"* may be dumped back into the water at depth
- Some prospect of piercing continental crust and artificially forming ore rich HTVs

"It's harder to get into the deep sea than it is to get into space"

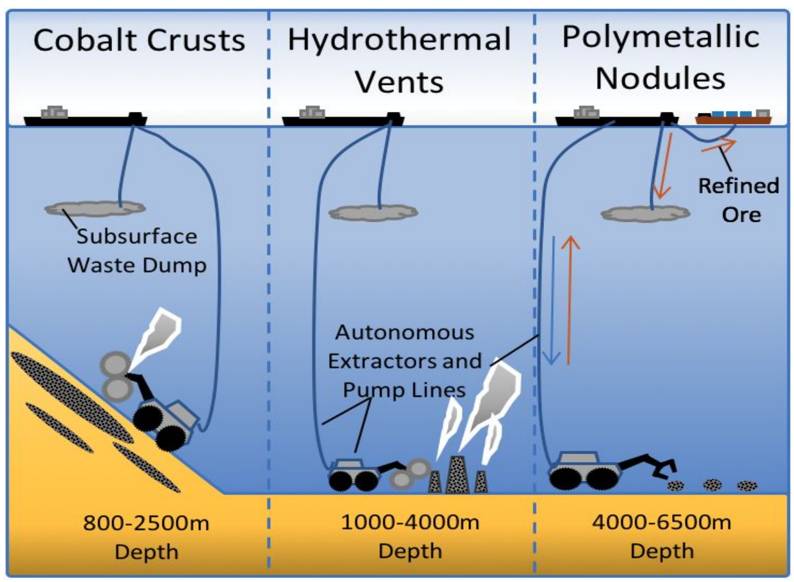
- Dr. Andrew Thaler, Marine Consultant

The Rewards are potentially massive:

- Ores expected to be 10x more concentrated than their terrestrial counterparts
- EU estimates 10% of mineral production to come from the ocean floors by 2030
- A particular location of interest in international waters is the *Clarion-Clipperton Zone* (CCZ), southeast of Hawaii. The estimated mineral deposits for this area alone compared to their terrestrial counterparts are massive (see table)

Element	CCZ	Land	Ratio
Manganese	5992	630	951%
Copper	226	690	33%
Titanium	67	414	16%
Rare Earths	15	110	14%
Nickel	274	80	343%
Molybdenum	12	10	120%
Lithium	2.8	13	22%
Cobalt	44	7.5	587%

Relative comparison of estimated ore content of CCZ and all estimated, economically recoverable land reserves in 2013 (million tonnes).



A Winner *for this race may be emerging. One company, Nautilus Minerals Inc, is a clear industry leader. It is due to begin extraction of minerals from a deep sea HTV within the territorial waters of Papua New Guinea* ***early next year*** *(2019). The project, with a projected profit of $58 million and a Return of Investment of 28%, looks to be a highly lucrative venture for both the company and the local government which holds a 15% stake in the project.*

Industry representatives claim that if done well DSM could ***"...significantly reduce social & environmental impacts compared to terrestrial [mines]"***

- Nautilus Minerals Inc.

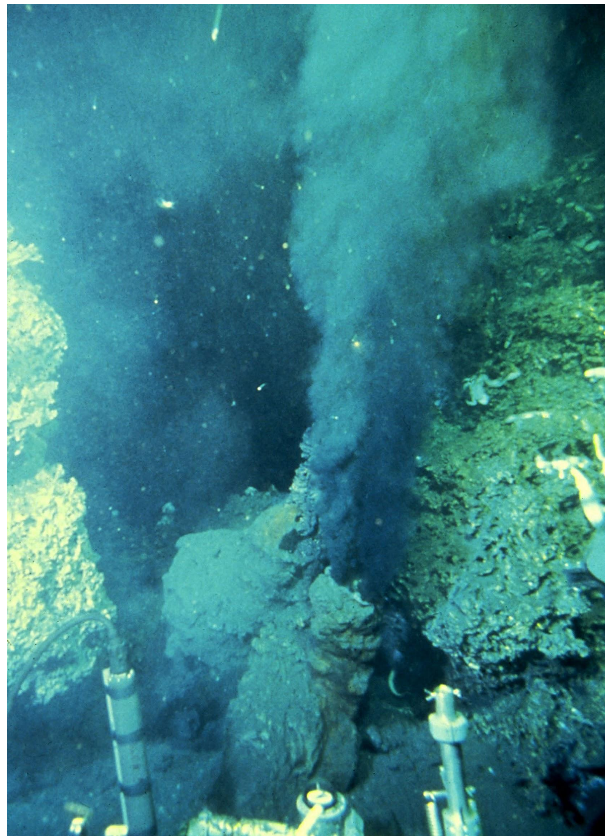
Biodiversity & Ecology Overview

Knowledge & Discovery

New secrets in the deep sea are always being uncovered. The discovery of hydrothermal vents in 1977 showed life could survive without ever needing the sun. 4x as many people have been to the moon than the deepest part of the ocean. More recently, skates were found to walk on the seafloor and use deep sea volcanism for natural egg incubation. Other studies found evidence that life may have begun in the deep sea via chemosynthesis at hydrothermal vents. What else is there to find?

"Every time you dive, you discover a new species"
- Dr. Joe Jones, Deep Sea Biologist

At right, the public sees a hydrothermal vent for the first time on the cover of Science Magazine in 1980
Courtesy NOAA | Spiess, MacDonald et al.



Key Facts
200 meters deep
90% of life on planet
95% of global inhabitable volume

Key Gaps
0.0001% explored
millions more species to discover
<1% has environmental protection

Deep Sea Ecosystem Services

- economically important fisheries
- biogeochemical cycling
- thermoregulation & CO_2 capture
- biotechnology & medicine
- mining
- eco-tourism

High vulnerability | Low resilience

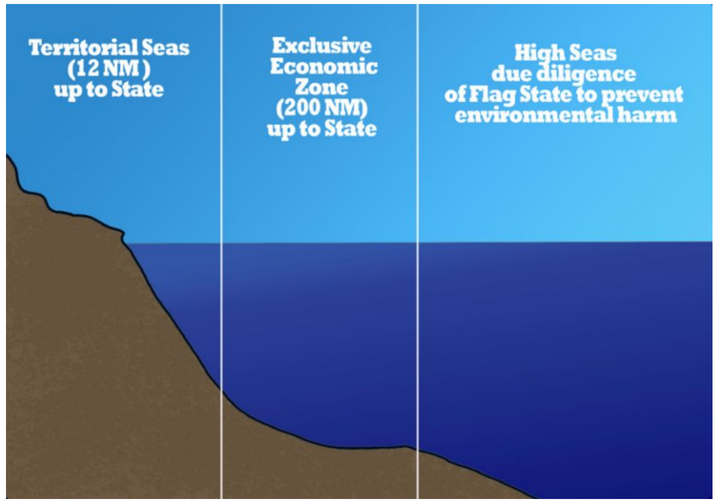
- Suitable mining sites on hydrothermal vents and seamounts often coincide with biodiversity hotspots where 70% of species are endemic
- Exploratory studies have suggested physical and chemical disturbances impact the immediate and surrounding water layers
- Some fauna can recover quickly but full ecosystem recovery post-mining could be slow. Some estimate that complete recovery could take up to 1000 years

Yeti Crab Courtesy MBARI | PAR 5 | Vrijenhoek

"The deep sea is the most biodiverse ecosystem on the planet, more even than the Amazon rainforest or coral reefs"
- Dr. Andrew Thaler, Marine Consultant

"The deep sea is the foundation of the Earth's life support system"
- Dr. Alex Rogers, Ocean Explorer

Policy & Governance Overview



Current Governance

Territorial Waters

Within a nation's Territorial Waters and Exclusive Economic Zone (EEZ) and in some instances within a nation's continental shelf, mining of the seabed is regulated by the relevant state.

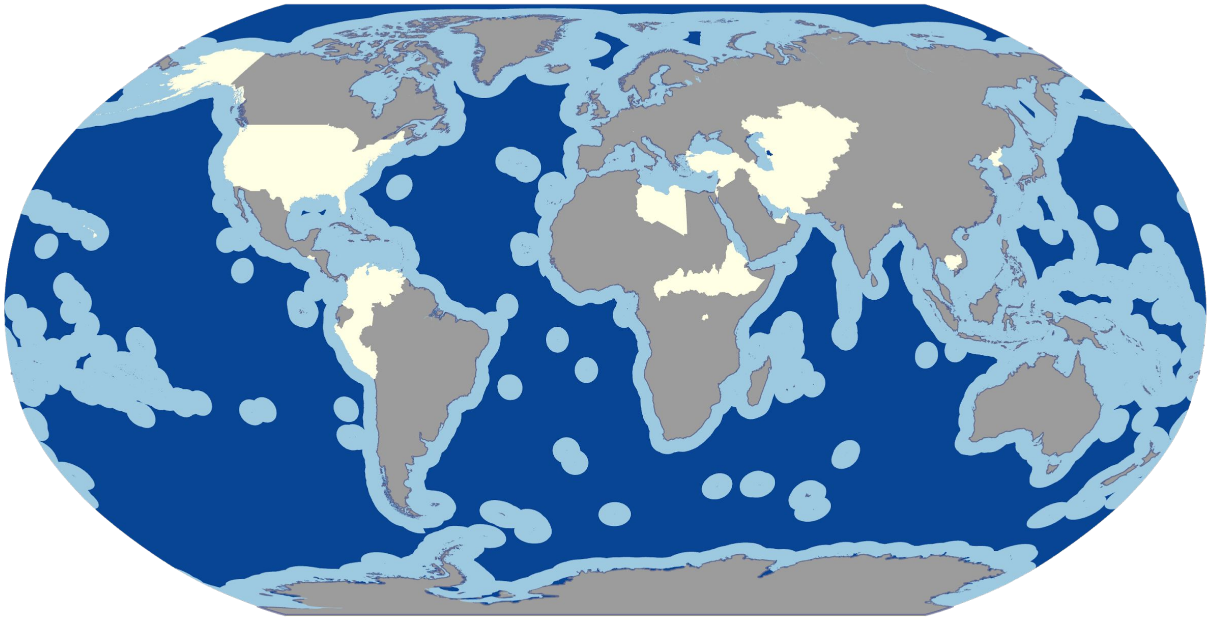
International Waters

Most deep sea mineral deposits are located in the High Seas or international waters, as defined by the United Nations Convention Law of the Sea (UNCLOS). As such, international regulation and common standards must exist for environmental safety. UNCLOS Part VI and the 1994 Implementation Act created standards for which countries must act with regards to both deep sea mining and marine research in the area. Each state is required to act with "due diligence" to make sure seabed activities in international waters by flagged vessels are carried out responsibly.

In defining the term "due diligence" an international tribunal came to the conclusion that the state acting as a sponsor of any entity involved in mining is obliged to adopt and enforce laws, regulations and administrative measures at all times that are at least as stringent as ISA regulations. Those rules and standards must include a *precautionary approach*; *best environmental practices*; *guarantees technically* and *financially* by the contractor; *requirements to provide recourse with compensation*; and an equally *stringent Environmental Impact Assessment* for developed and developing states. However, even with a UN International Authority, regulation is lacking with the deep sea mining arena with many countries providing almost no regulation.

> ***"A [deep sea mining] governance framework should balance people and the planet"***
> *- Kerry McCarthy, MP*

While 149 nation states have ratified UNCLOS a number of countries maintain "observer" status; notably this includes the United States. In doing so - while they may obey UNCLOS as the de facto law of the sea - they do not necessarily acknowledge the UN's authority in the matter *per se*. There is therefore, concern in some circles as to the strength of the current governance system. The beginning of major mining operations will test the existing governance frameworks of the UN and national governments.



Map of global EEZs (light blue) and observer states (light beige) to UNCLOS. Both EEZs and the ocean floor outside of them ("the Area") are potentially open to deep sea mining

The International Seabed Authority

The UNCLOS Act also resulted in the creation of the **International Seabed Authority** (ISA) who, according to its mandate from the UN, holds the sole right to grant licenses for deep sea mining in international waters. The ISA has so far granted:

- 27 explorative contracts (15 within the CCZ alone)
- 1.4 million km^2 of ocean floor licensed for DSM
- The companies receiving these licenses are mostly sponsored or directly managed by western or rapidly industrialising state governments

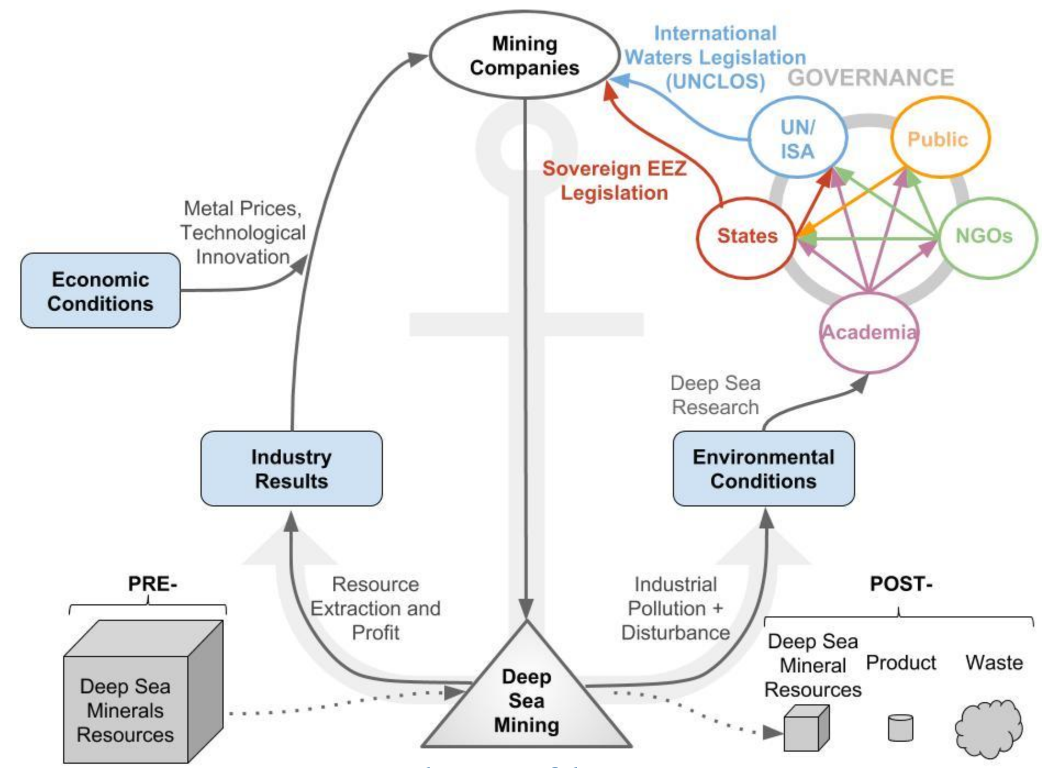
"The deep sea has a PR problem"
- Dr. Andrew Thaler, Marine Consultant

"How we view the ocean determines how we treat it"
- Dr. Joe Jones, Deep Sea Biologist

The Public and Deep Sea Mining

NGOs and the public often prioritize other marine issues, such as plastics pollution, overfishing, and petroleum exploration which makes public policy on the deep sea difficult to initiate. The deep sea, which lies hundreds of miles from where we live, has less context for the general public. However, media campaigns such as BBC's Blue Planet II show how a glimpse into the deep can capture the public's attention. Several deep sea scientists have recently proposed an anglerfish emoji ( ), so people can continue the conversation in their everyday lives.

Understanding the System



A systems diagram of deep sea mining

Stakeholders and Power Brokers

The deep sea mining system is only now emerging, and is displaying a structure similar to mining on land. The key exception is that while the mining companies are firmly anchored to the market, other stakeholders lack the context and power needed to impact the system. What gaps are there in this system and what might be the options for change?

Gaps	Levers
The market feedback loop operates faster than the environmental feedback loop, leading to a potentially unstable system	Accelerate the drivers of the environmental feedback loop (via research, public awareness & education) and slow the drivers of the market feedback loop (via economic incentives, governance regimes)
Certain system actors (government and the public) lack leverage	Increase those actors' access to the decision making table, increase enforcement mechanisms
High uncertainties are present for certain system nodes and linkages	Increase deep sea research to fill knowledge gaps, foster thought leadership in advance of major changes to the system, use sustainability frameworks to plan future steps
System actors have limited interaction or are in opposition	Increase transparency and accountability, foster communication and participation from marginalized actors

Responding to the System

In addition to filling these gaps and utilizing existing system levers, we have identified two elements to shift the overall system state to achieve sustainable development:

Shift the Paradigm

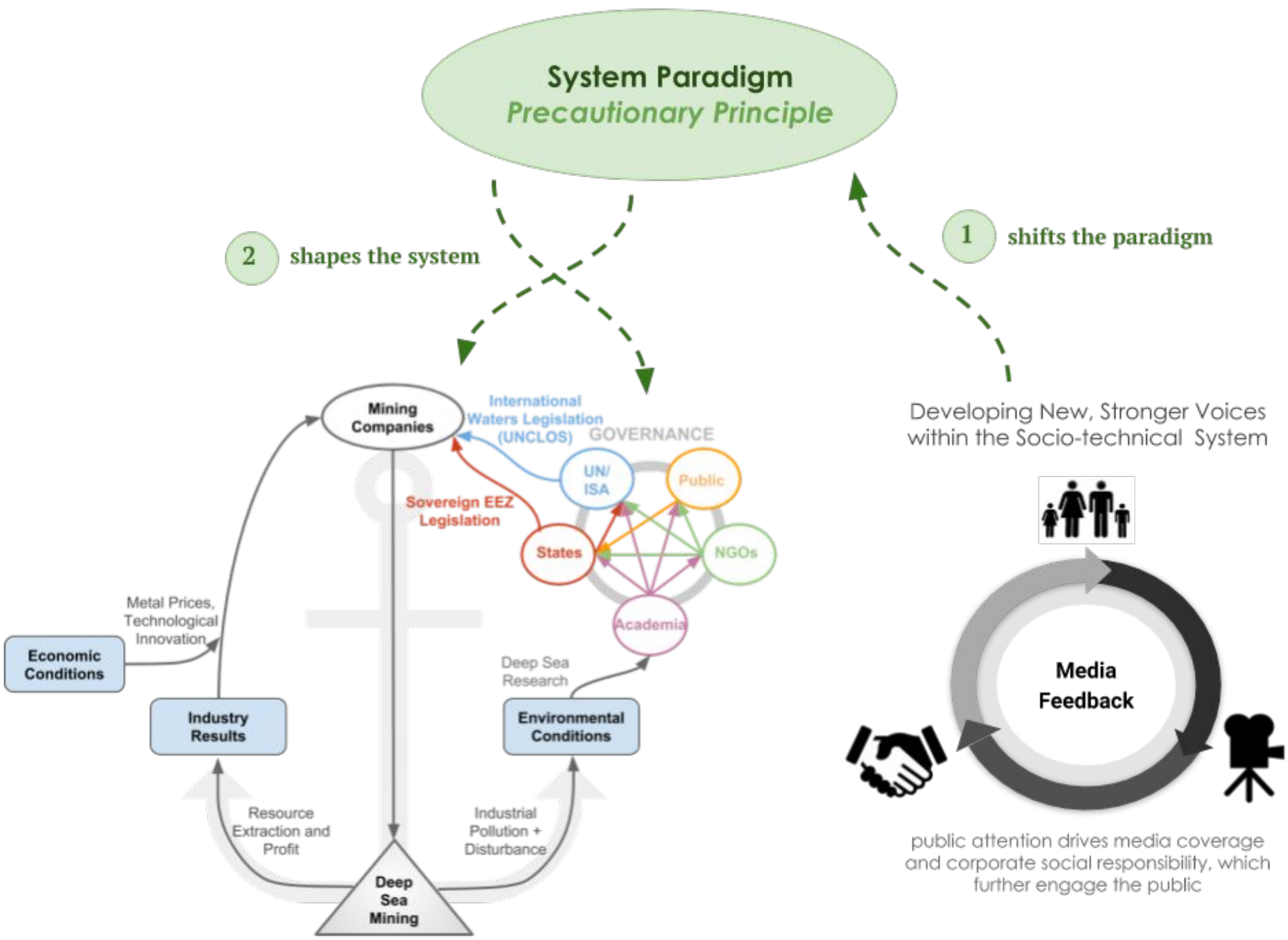
Use New Actors to Accelerate Change

- Create a new feedback loop between the public, media, and businesses, creating space in the system for new voices

Shape the System

Precautionary Principle

- This framework pushes sustainability first, creating a balanced system that operates predictably and smoothly



Remaking the System

A new systems diagram incorporating changes and additions which could lead to a new socio-ecological landscape that fosters sustainable development.

Creating Sustainable Development

With underlying drivers such as increased global consumption and a growing societal reliance on technology, deep sea mining will play a significant role in future supply chains. Currently this issue may feel far removed both physically and temporally, but the field is developing rapidly and it is key that global actors are proactive in ensuring the system develops in a sustainable direction that is beneficial for both people and planet.

There are indications that deep sea mining could join existing environmental problems - such as climate change or habitat loss - where system failures have led to the prioritisation of short-term economic gains over long term stability. However, the ISA and UNCLOS were founded on the principles of ensuring the "common heritage of mankind" is exploited for "the benefits of mankind as a whole" (UNCLOS Preamble).

The success of programmes such as the BBC's Blue Planet II shows the public can cherish these distant and unfamiliar worlds. While existing environmental impact assessments and governance frameworks are a good start, strengthening public engagement is a key missing element of the existing system that will drive future sustainability.

We hope that this report is a tool that works both to continue to raise awareness on this issue and is a step towards identifying how best to achieve a world of deep sea mining that is profitable, equitable and accountable. By highlighting gaps and levers to the current system we identify areas that can drive change and create lasting impact. Our systems thinking solutions can form the beginnings of a new direction for the field that results in sustainable development that balances humanity and the planet we inhabit.

ROV mining a hydrothermal vent. Courtesy: Nautilus Minerals Corporate Communications