REFLECTIONS ON DEEP SEA MINING DEVELOPMENT: MORE THAN TECHNOLOGY ALONE

Henk van Muijen
IHC Mining
INTRODUCTION TO ROYAL IHC

Royal IHC is:

- Based in The Netherlands with two shipyards, offices worldwide & over 2,300 employees
- A technical service supplier for marine industry, mining, oil & gas and renewables
- A dredging equipment supplier
- A mining equipment supplier
- A O&G construction equipment supplier
- Integrates its own equipment and that of others into the ships it builds
WHO WE ARE: IHC MINING

<table>
<thead>
<tr>
<th>Dry Mining</th>
<th>Wet Mining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inland</td>
<td>Sand</td>
</tr>
<tr>
<td></td>
<td>Salt</td>
</tr>
<tr>
<td></td>
<td>Gold</td>
</tr>
<tr>
<td>Nearshore</td>
<td>Tin</td>
</tr>
<tr>
<td></td>
<td>Diamonds</td>
</tr>
<tr>
<td>Deep sea</td>
<td>Gold</td>
</tr>
</tbody>
</table>

The technology innovator.
THIS PRESENTATION IS ON DEEP SEA MINING

• Development of deep sea mining technology is already challenging
• A successful implementation, however, requires focus on other constraints as well
• Resource determination, economic evaluation, sustainability issues and an available legal framework should be integrated simultaneously with technology development
• Successful deep sea mining development requires an approach in which these different angles have to be considered
WHY DEEP SEA MINING?

Seventy percent of the earth’s surface is covered by sea and ocean. Yet we seem to know less about ocean space than outer space.

The ocean is the last frontier for science and exploration on this planet. [James Cameron]

The ocean is the last frontier for science and exploration on this planet. [James Cameron]
CONSEQUENCES ECONOMIC GROWTH: IMPACT GROWING POPULATION.

World GDP per capita\(^1\)
(US$'000, real 2005 PPP)

Bubble size = GDP of US$5 trillion (real 2005 PPP)

Source: Global Insight; BNP Billon analysis.
1. All figures for 2009 unless mentioned otherwise.

The technology innovator.
CONSEQUENCES ECONOMIC GROWTH: GROWING NEEDS OF MINERALS.

The inflection point is yet to be reached for many of our products. Percentage of saturation level.

*Saturation level – point at which consumption per capita does not increase with income levels.
Source: Rio Tinto.
Global Cobalt production: 99000 mT/a
Additional demand: 36000 mT/a

**CHINA IS LEADING THE CHARGE**
Lithium-ion megafactories in China to grow capacity 6X by 2020

<table>
<thead>
<tr>
<th>Capacity in 2016</th>
<th>Capacity in 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 GWh</td>
<td>174 GWh</td>
</tr>
</tbody>
</table>

Global lithium-ion battery production capacity will increase by 521% between 2016 and 2020.
CONSEQUENCES GREEN ECONOMY.

Lithium Ion batteries
- NCA: Cathode: 80% nickel, 15% cobalt and 5% aluminium
- NCM: Cathode: Equal parts of nickel, manganese, and cobalt

Fact: 43% of cobalt demand comes from Lithium Ion batteries
Fact: Cobalt production - 98% byproduct of nickel and copper production
Fact: 54% of cobalt production 2016 from Dem. Rep. Congo

Source: Mining Journal 8-21 September 2017
TARGET MINERALS

Offshore placers: Diamonds, gold, tin, heavy minerals (Ti-Zr)

- Phosphates
- Cobalt Rich Crust (Co, Mn, Ni)
- Seafloor Massive Sulphides (Cu, Au, Zn)
- Nodules (Mn, Ni, Cu, Co, REE)

Source: GRID-UNEP
FOCUS SEABED RESOURCES

Poly metallic nodules

- Manganese: 29%
- Nickel*: 1.4%
- Copper*: 1.3%
- Cobalt*: 0.25%
- Rare Earth*: traces
- Magnesium: 0.5%
- Potassium: 0.5%
- Titanium: 0.2%

SMS deposits

- Copper*: 7 - 8%
- Zinc*: 2 – 3 %
- Gold*: 3 – 5 g/t
- Silver*: 23 – 56 g/t
DEEP SEA MINING

RESOURCE

1. Exploration
2. Resource assessment, evaluation and planning
3. Extraction, lifting and surface operations
4. Offshore and onshore logistics
5. Processing
6. Distribution and sales
7. Mine closure and site remediation

The technology innovator.

REVENUE
RISK MINIMIZATION

Challenges + innovation
- Technology
- Business plans
- Processes
- Legislation
- Ecology

USE OF RESOURCES

The technology innovator.
TECHNOLOGY & OPERATIONAL CHALLENGES – REQUIRED EXPERTISE
How mature is DSM Technology?

**Mining System @ today:**
- Ore Processing: TRL 3 - 4
- Ore Transfer: TRL 3 - 4
- Vessel: TRL 6 - 7
- Vertical Tr’sport: TRL 3 - 4
- Mine Vehicle: TRL 3 – 5

All to TRL 7+ by 2020/22

**e.g. Polymetallic Nodules**

**TRL**
- TRL 9 (High Risk)...
- TRL 1 (Low Risk)

**The technology innovator.**
DEEP SEA MINING – TECHNOLOGY DEVELOPMENT

DEEP SEA
Polymetallic Nodules
Resource definition advanced with country and commercial player focus.

Deep Sea Technology Focus
1. Midas - Environment.
2. Blue Mining – VTS.

The technology innovator.
DEEP SEA MINING – BLUE MINING

- Resource mapping & survey
- Resource definition
- Business case (SMS, Poly Met. Nodules)
- Technology development
- Vertical transport
  - Slurry behavior
  - Structural behavior (dynamics)
  - Monitoring and control
  - Development of critical components
- Technology demonstrators
  - Open PM motor
  - Ship to ship transfer

*The technology innovator.*
TECHNOLOGY – VTS

The technology innovator.
DEEP SEA MINING – RESULTS BLUE MINING

The technology innovator.
DEEP SEA MINING – RESULTS BLUE MINING

The technology innovator.
DEEP SEA MINING – BLUE NODULES

- Business case
- Subsea and seafloor processing
- Crawler development
  - Propulsion
  - Collector
  - Monitoring and control
- Lab tests
  - MTI lab
  - Deltanres
- Field tests
  - Cruises to test area in North Sea (2x) (NIOZ)
  - Cruise to CCZ (GSR)

The technology innovator.
SEABED TECHNOLOGY
DEEP SEA MINING – RESULTS
BLUE NODULES
DEEP SEA MINING – RESULTS BLUE NODULES

The technology innova...
BUSINESS CASE: DEVELOPMENTS FOR TOTAL MINING LIFE CYCLE

Exploration management focused on:
- Identification and assessment of mineral resource potential
- Coordination of site surveys, mapping and sampling programs
- Advice on regulatory and environmental reporting

Exploration evaluation focused on:
- (Pre-) Master plan
- (Pre-) Scoping study
- Pre-feasibility
- Def. feasibility
- Equipment procurement
- Mine construction

Construction

Evaluation studies focused on:
- Mining
  - Mine method selection
  - Mine planning
  - Costing
  - Concept design
  - Equipment design base
  - Due diligence
    - Technical
    - Financial
- Mineral processing
  - Wet separation techniques
  - Process Flow Diagram (PFD) development
  - Mass balance calculations
  - Game of capacities
  - Design envelop

Operation

Operational support
- Performance improvement
- Troubleshooting

Time

Integrated dredge and marine mining solutions over total mining life cycle

The technology innovator.
SUSTAINABLE DEEP SEA MINING CHALLENGES

- Potential mining impact
- Knowledge-gap deep-sea ecosystems and potential environmental impacts
- Mitigating measures
- Capacity building
ASSESSING AND MINIMIZING ENVIRONMENTAL IMPACTS OF DEEP-SEA POLYMETALLIC NODULE HARVESTING, PROCESSING, AND TRANSPORT

Sources of environmental pressures at the mine site:

• Light, pollution
• Trans-shipment plume Returned water
• Noise, vibration
• Large area impacted (connectivity, ecosystem function, recovery etc)
• Generation of benthic plume
• Substrate removal (nodules)
• Removal of surficial sediment layer
• Sediment compaction
DEVELOPMENTS FOR TOTAL MINING LIFE CYCLE

**Exploration management focused on:**
- Identification and assessment of mineral resource potential
- Coordination of site surveys, mapping and sampling programs
- Advice on regulatory and environmental reporting

**Ecology Legislation**

**Evaluation studies focused on:**
- Mining
  - Mine method selection
  - Mine planning
  - Costing
  - Concept design
  - Equipment design base
  - Due diligence
    - Technical
    - Financial
- Mineral processing
  - Wet separation techniques
  - Process Flow Diagram (PFD) development
  - Mass balance calculations
  - Game of capacities
  - Design envelop

**Integrated dredge and marine mining solutions over total mining life cycle**

*The technology innovator.*
Leaders’ Declaration G7 Summit Germany, 7-8 June 2015

Protection of the Marine Environment
We acknowledge that marine litter, in particular plastic litter, poses a global challenge, directly affecting marine and coastal life and ecosystems and potentially also human health. Accordingly, increased effectiveness and intensity of work is required to combat marine litter striving to initiate a global movement. The G7 commits to priority actions and solutions to combat marine litter as set out in the annex, stressing the need to address land- and sea-based sources, removal actions, as well as education, research and outreach.

We, the G7, take note of the growing interest in deep sea mining beyond the limits of national jurisdiction and the opportunities it presents. We call on the International Seabed Authority to continue, with early involvement of all relevant stakeholders, its work on a clear, effective and transparent code for sustainable deep sea mining, taking into account the interests of developing states. Key priorities include setting up regulatory certainty and predictability for investors and enhancing the effective protection of the marine environment from harmful effects that may arise from deep sea mining. We are committed to taking a precautionary approach in deep sea mining activities, and to conducting environmental impact assessments and scientific research.

1. Acknowledging growing interest/opportunities in DSM
2. Requirements for development of legislation
3. De-risking + interests of all stakeholders
4. Effective protection of marine environment
5. Precautionary approach based on assessments + scientific research

The technology innovator.
GEOPOLICY + STAKEHOLDER INTERESTS

The technology innovator.
Proposal for an integrated development framework for seabed mining projects
BUSINESS MODEL CHALLENGES; PLAYING FIELD / MINING CYCLE; UNDERSTANDING EACH OTHERS OBJECTIVES & REQUIREMENTS
DEEP SEA MINING – THE NEXT STEP

Deep Sea Technology Focus
1. Midas - Environment.
2. Blue Mining – VTS.

The technology innovator.

Integrated prototype demonstrated in operational environment = trl 7
Full scale mining = trl 9
CONCLUDING REMARKS

• Next steps will focus on real applications (commercial operation and system integration tests)
• Not completely clear yet; trial with prototype equipment
• We know what is of importance; protecting stakeholder interests
• Long term development; potential is interesting due to scarcity of resources
• Work together in order to get a sustainable development
• Level playing field based on common legislation is a necessity to protect interest of all stakeholders;
• However, mining market will determine commercial steps
• That is ok, as long as it is a sustainable step !!
• EU project in which we all participate can bring us to a final phase

The technology innovator.
CONTACT DETAILS

IHC Mining BV
Smitweg 6, Kinderdijk
P. O. Box 9
2960 AA Kinderdijk
The Netherlands
T +31 88 015 25 35
mining@royalihc.com
www.royalihc.com