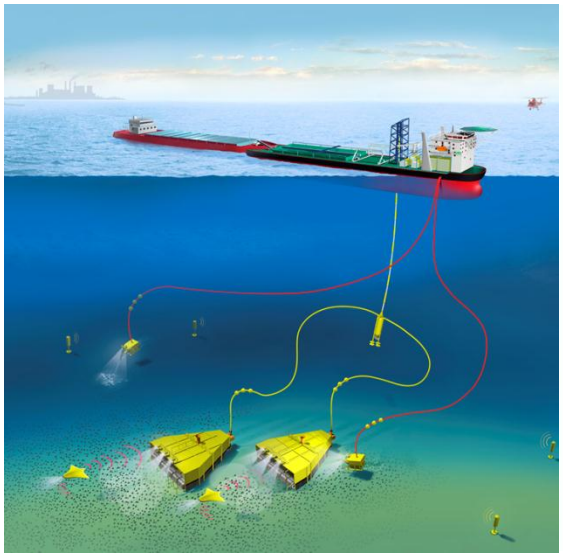
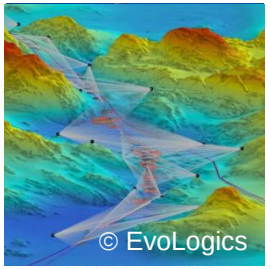
Preferred partner



Ecological and
sustainable
deep-sea mining



Technological and economical challenges of manganese nodule mining in the Clarion-Clipperton-Zone

Future Ocean – Seafloor Mineral Resources
March, 19th 2013, Kiel

Technology & Innovation | Aker Wirth GmbH, Erkelenz

Dr. Steffen Knodt: steffen.knodt@akersolutions.com

Christian Dornieden: christian.dornieden@akersolutions.com

Open pit mines are facing challenges in the near future

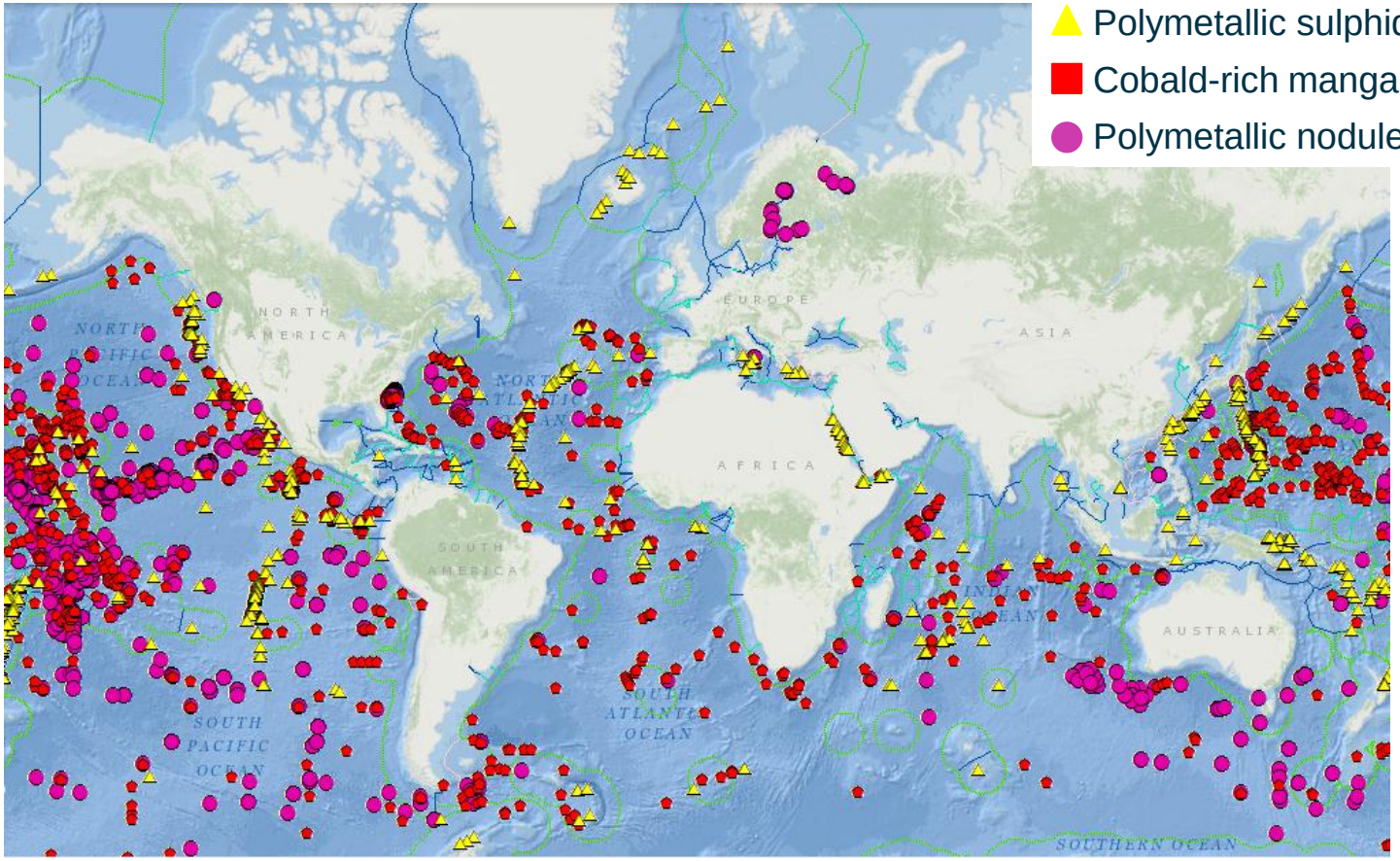
- Discoveries of higher grade deposits are becoming less frequent (declining average grades)
- Depth of open pit mines at their limits

- More underground mines are producing copper at a smaller output capacity
- Infrastructure challenges (remote locations)

- Aker Wirth offers unique cutting technologies and machines for infra-structure tunnels in hard rock deposits

Global distribution of known marine mineral resources

Marine mineral resources as a source for metallic raw materials with high ratios of important metals



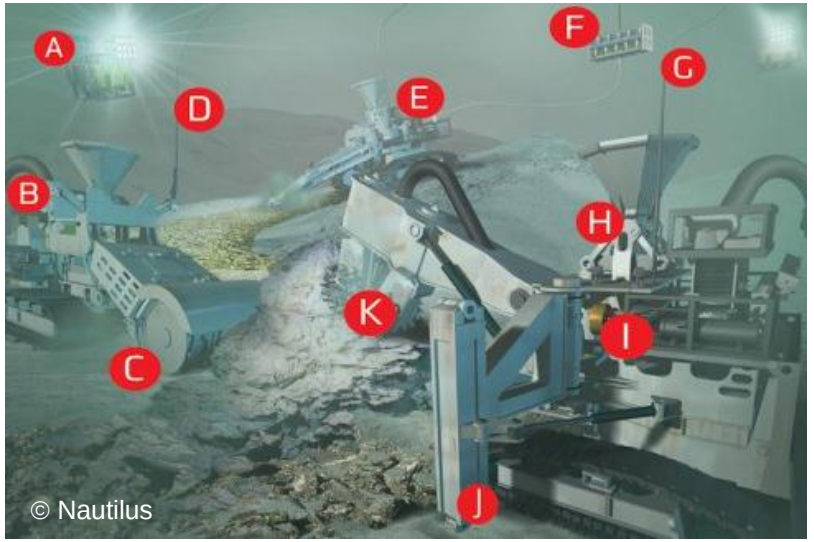
© ISA

Manifold types of marine mineral resources

Seafloor Massive Sulphides	Cobalt-rich Manganese Crusts	Manganese Nodules
		
© Nautilus Minerals	© ISA	© BGR
→ Cu, Zn, Pb, Au	→ Co, Ni	→ Ni, Cu, Co, Mn
1,000 – 3,000 m	1,000 – 2,500 m	4,000 – 6,000 m

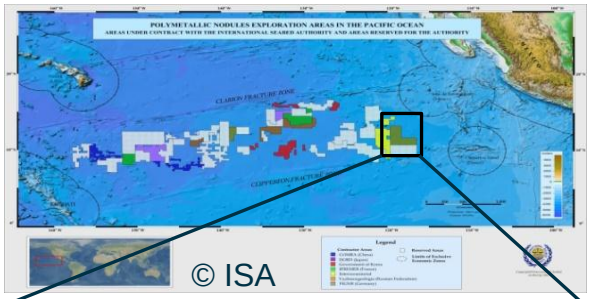
water depths

Benefits of seafloor minerals compared to onshore mines

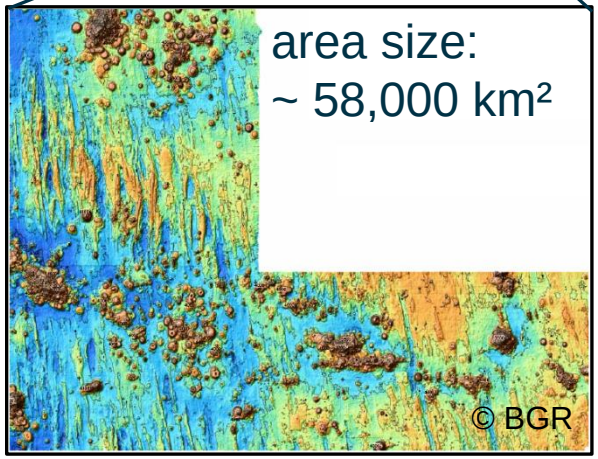


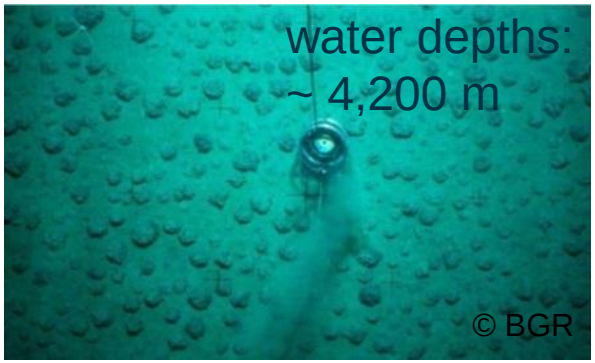
- **Infrastructure expense**
  no site-specific infrastructure, moveable mining systems
- **Flexibility**
  mining ships can move to different types of deposits / minerals to suit market conditions
- **Overburden**
  no overburden to be removed and lower waste to ore ratio
- **Environmental concerns**
  minimal carbon footprint and small environmental impact

Basic conditions for sustainable manganese nodule mining



German license territory





Sustainable, ecological choice of mining areas:

- occupancy rate > 10 kg / m²
- gradient < 3°

→ 18 % of the eastern German license territory: 10,500 km²

→ compliance of guidelines for protection of environment

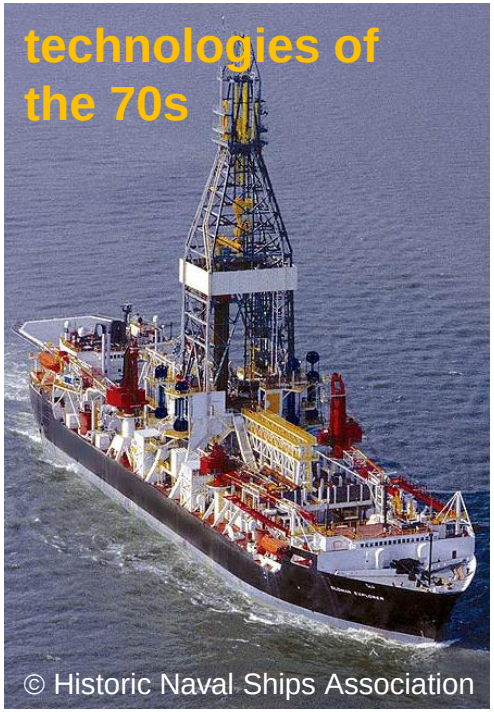
Conveying 2.2 Mio. t manganese nodules per year allows mining for approx. 42 years

93 Mio. t of manganese nodules
→ value of metals > 71 Mia. €

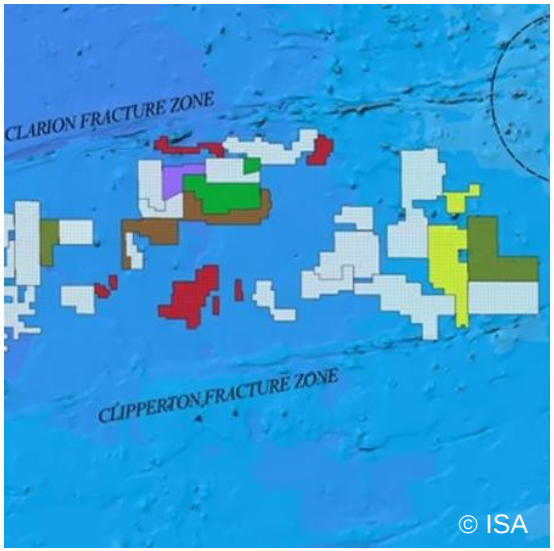
Technical challenges of the deep sea – Strategies & Solutions

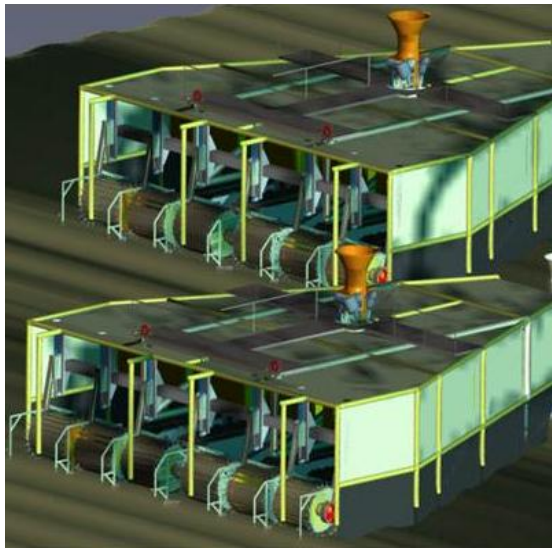
Water depth & distance to shore	Restrictions in communication & visibility	Effectivity of operation & production
▪ pressure compensation ▪ remote operating or autonomous systems ▪ maintenance free durable systems	▪ using intelligent acoustic systems for positioning, monitoring, communication ▪ specially adapted visualisation software ▪ safety & emergency zones with stepwise autonomous emergency shut down	▪ exploration systems for mission planning ▪ standardized control & automation system ▪ flexible orientation & module-exchange ▪ monitoring & metering

Strong progress of offshore-technologies since the 70s

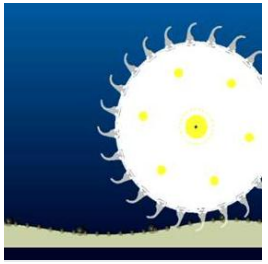


Performed studies manganese nodule deep sea mining





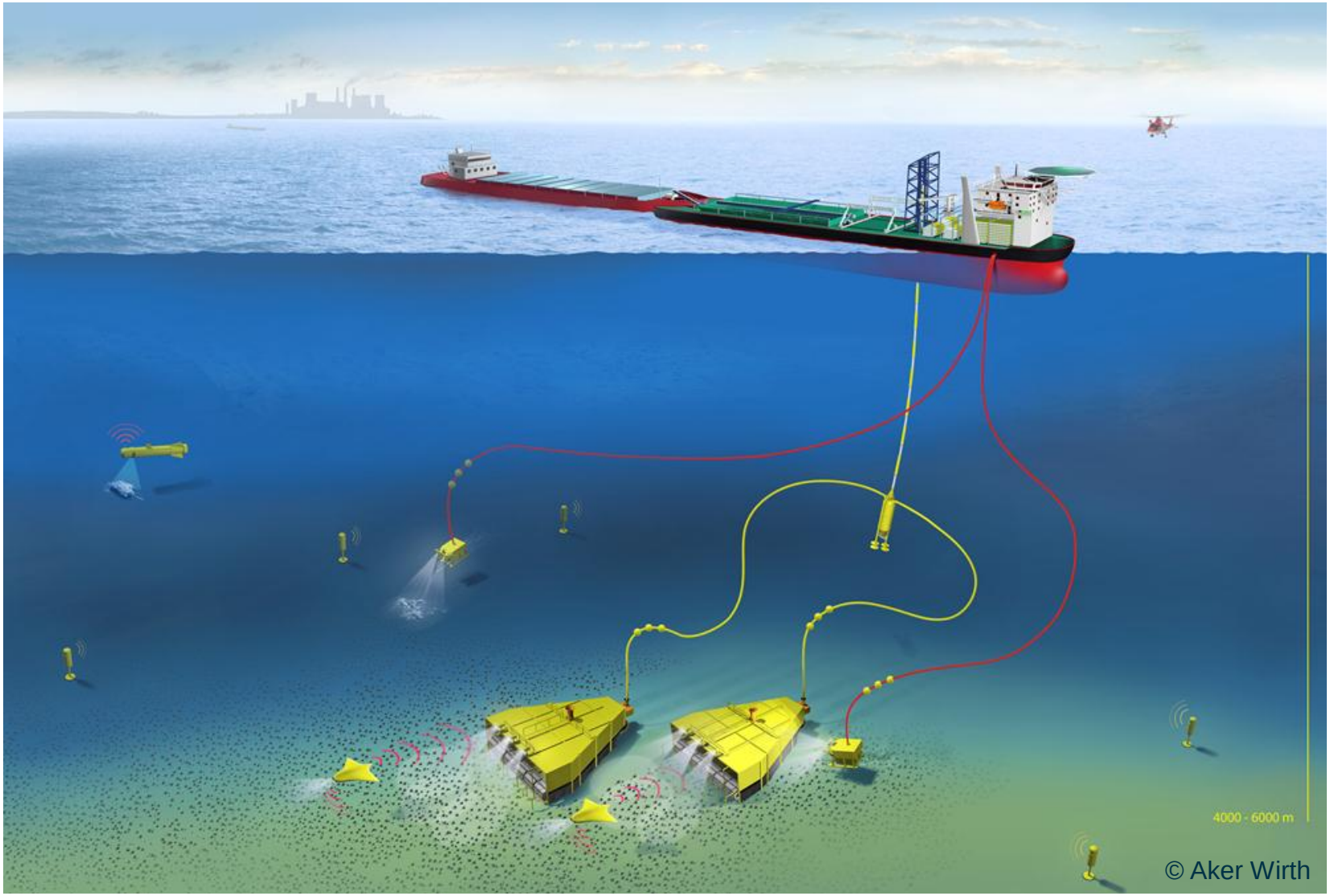
Ecological and sustainable subsea mining



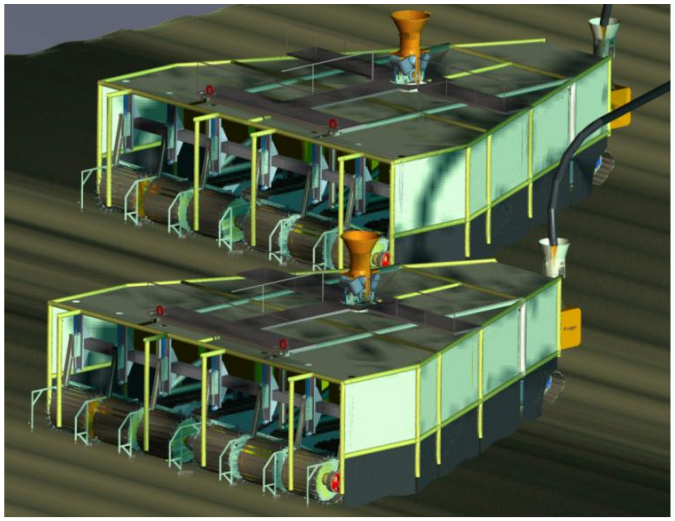
- Demonstrator Subsea Intervention Tool ISUP – 2009
- Technical concept study for the Federal Institute for Geosciences and Natural Resources (BGR) (administrator of the German licence territory) - 2010
- Profitability analysis - 2012

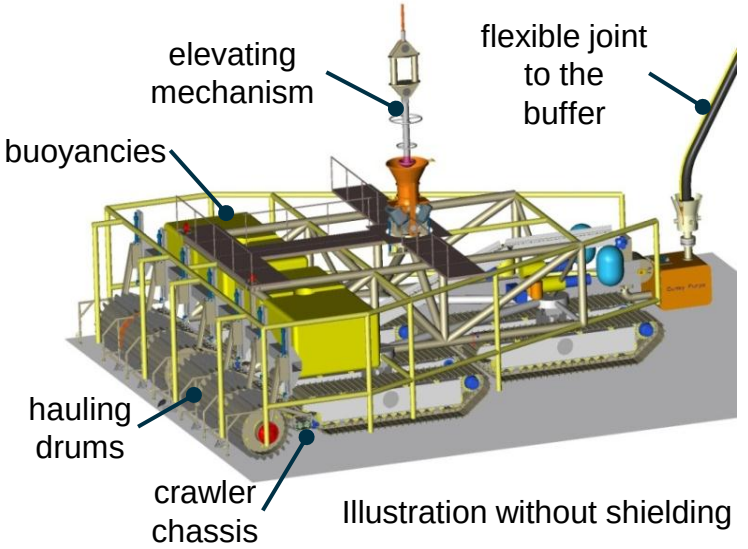
- Expansion of the system boundaries for offshore technologies from 3,000 m up to 4,500 m water depth

Manifold offshore-technologies are necessary for deep sea mining



Minimized impacts of the seafloor production system





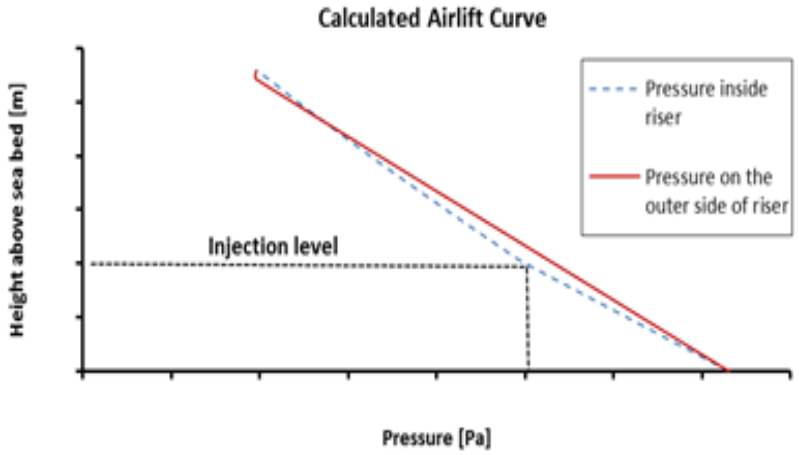
Minimized environmental impact:

- crawler chassis → minimal impact on the seafloor
- hauling drums → no plowing of the seafloor
- nodule cleaning at the collector → minimal turbidity
- totally shielded → minimal turbidity
- air-lift technology → no oil-leakage

Collector dimensions:

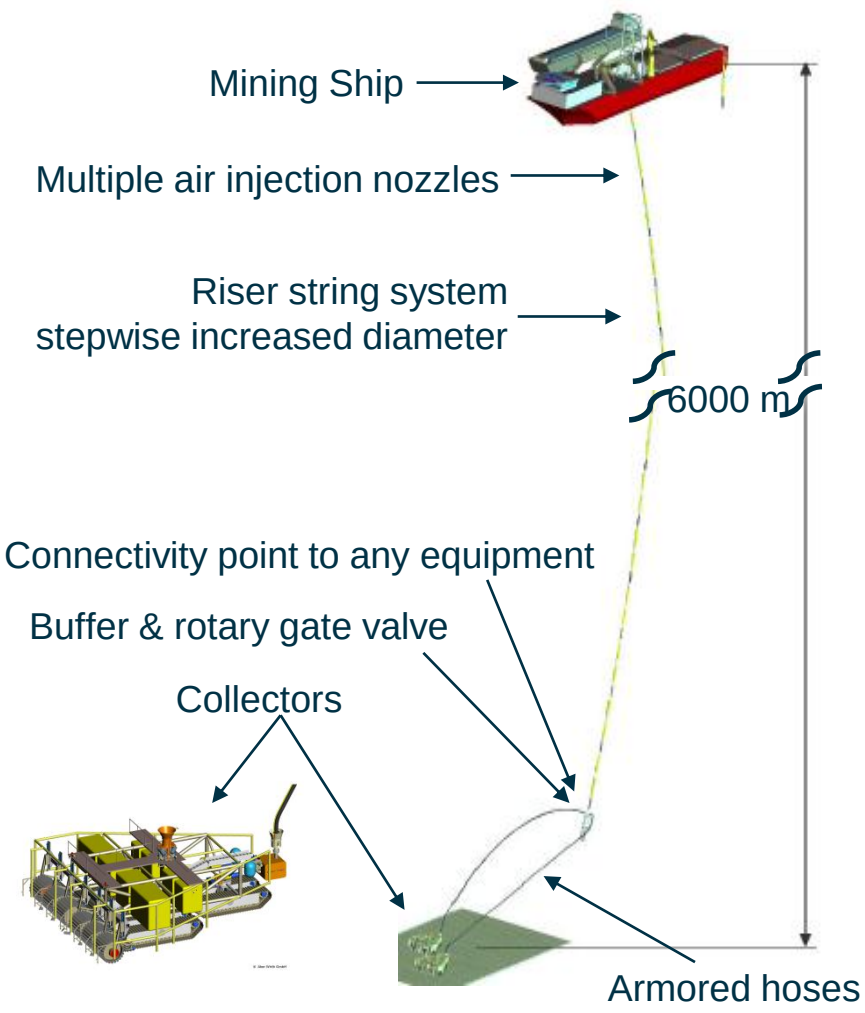
- width → 17 m
- weight → 250 t (100 t under water)

Functionality of the air-lift system



- air compressor mounted on topside
- compressed air is transported from a separate vertical pipe
- injecting compressed air horizontally into the riser pipe
- reduced phase density, the air-water mixture above injection level will adept a flow upwards
- due to the continuous injection of compressed air also a flow in the riser below injection level adapt
- upward flow of solids, if the fluid speed in the riser under injection level is higher as the ‘solid sink velocity’

Airlift system for ultra deep water subsea mining

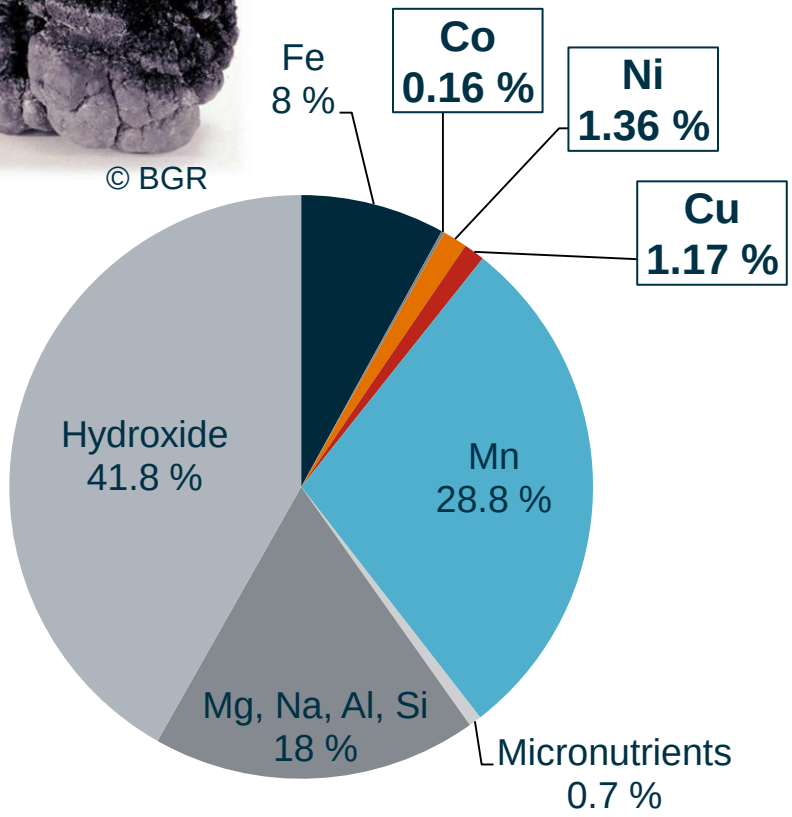


Main advantages of the airlift system

- wide range of particle size inside the riser string (theoretically close to inner passage Ø)
- steady flow conditions in riser string pipe without any valves, pistons etc.
- reducing mechanical systems subsea
  → all maintenance demanding systems staying on the vessel
  → no wear or blockage in pump system
- highest availability under rough conditions up to 98%

Challenges of the metallurgical process for manganese nodules


© BGR



- manganese nodules with high ratios of important metals
- processing for Co, Ni, Cu developed
  → recovery 89 % - 95 %

- price development and recovery uncertain for Mn
  → no consideration

- processing for strategic metals (micronutrients) in development
  → recovery uncertain
  → no consideration

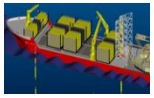
profitability analysis bases exclusively on familiar processing

Conservative analysis of all factors in the complete system

Capital / Operational Expenditures


Collector system


Riser string


Mining ship

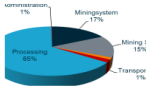

Transport ship (bulker)


Harbor facility / onshore logistic

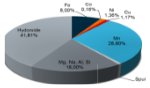

Processing

- **based on the Aker Wirth study from 2010**
- **detailing / actualizing in 2012**

Profitability analysis


Capital & Operational Expenditures


Price estimations for raw materials

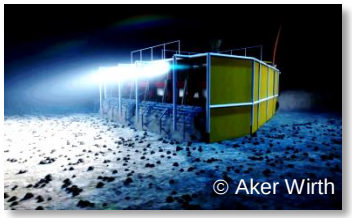

Recovery after processing


Chronological development of revenues

- **actual market situation**
- **scenario analysis 2020-2032 (nominal, worst-case, best-case)**

conservative evaluations
→ high expenditures
→ low revenues

Technologies are available, but a system integrator is missing



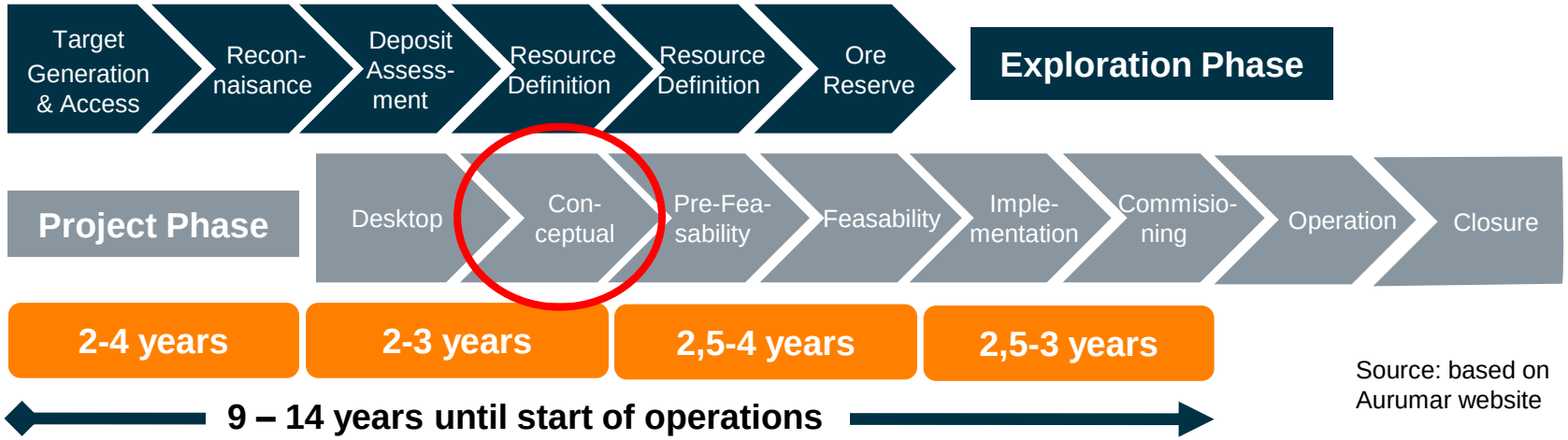
Technological & economic challenges

- Expansion of the system boundaries for offshore technologies from 3,000 m up to 4,500 m water depth
- Industrial testing of the mining and conveying system
- Proofing environmental safety and sustainability
- Developing the processing for strategic metals

Industrial-politic challenges

- Absence of a German, globally operating raw materials conglomerate
- To date there is worldwide no MMR system integrator in place
- Configuring an international political framework
- Creating investment plans for an industrial consortium

Next steps… Deep sea pilot mining test



Source: based on Aurumar website

Test objectives

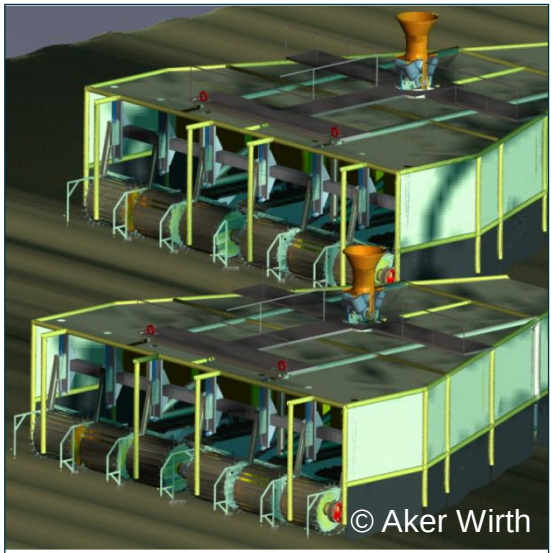
- Recover a defined quantity of manganese nodules from the seabed
- Test of relevant technical components of the deep sea mining system
- Assessment of environmental impacts

Test scenario

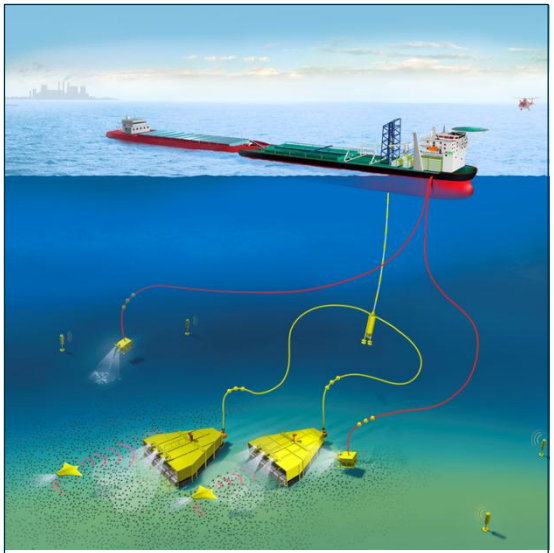
- Deployment of crawler and buffer on the sea bed with an appropriate flexible interface

Opportunities for a German marine mineral resources industry

sustainable



ecological



economical

Thank you for your attention!

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