



Scientific Challenges and Open Research Questions for Deep Sea Mining – a holistic approach -

3rd annual conference

Offshore & Deep Sea Mining 2016

28th-29th November 2016

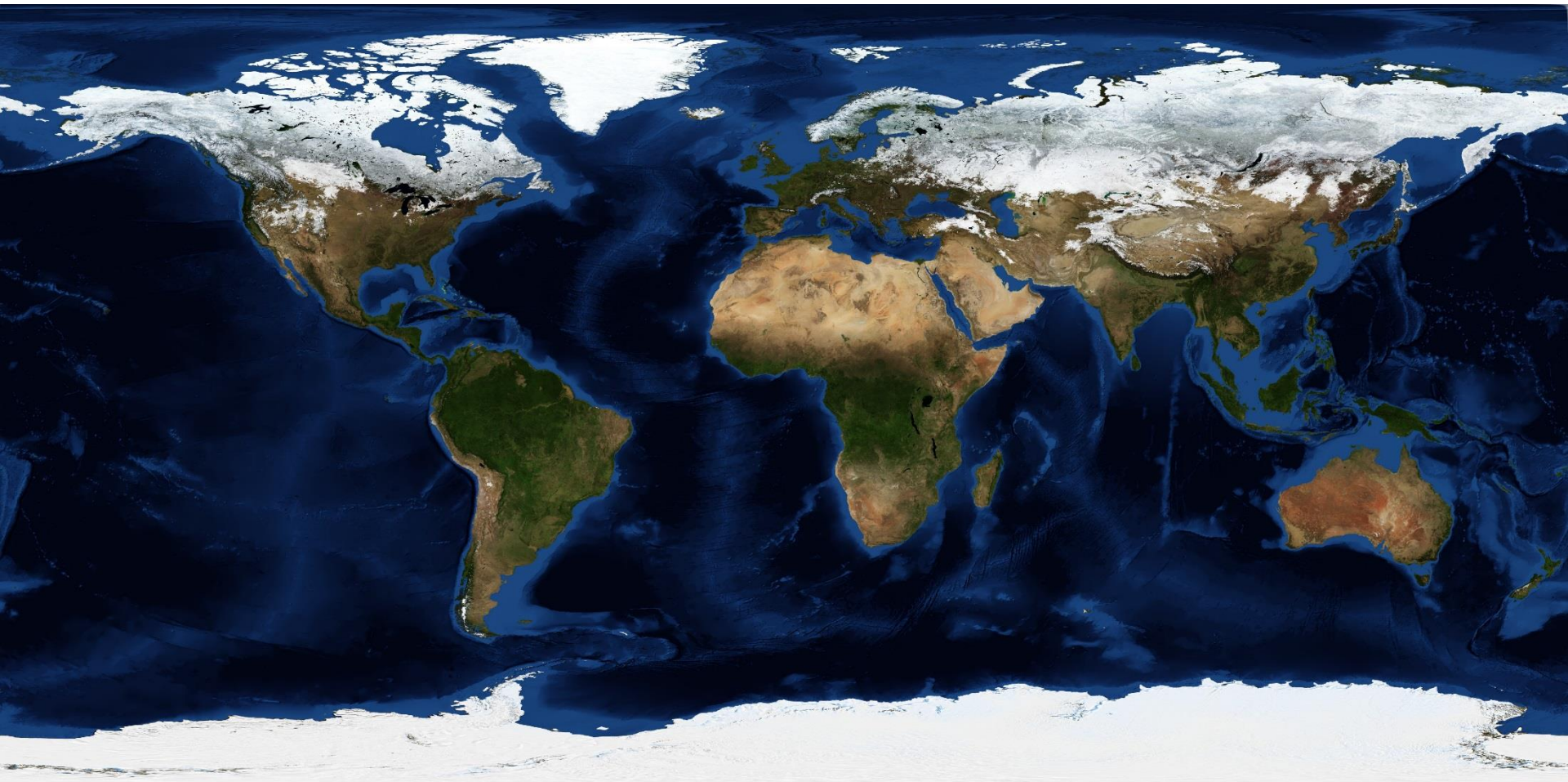
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Mining Situation (present and future)

- Extremely complex ore bodies
- Ore grades decline
- Economy of scale approach
- More complex regulations (Health, Safety, Environment)
- Recycling can't solve it all

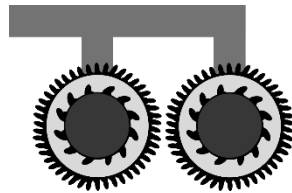


**Seafloor
Production
Equipment**

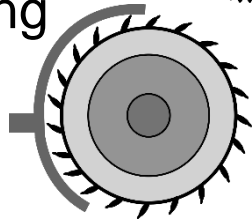
Seafloor Production Equipment/Rock Cutting

“Nautilus Minerals/SMD”

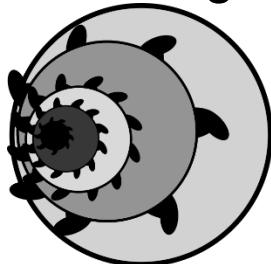
- Pre-cutting



- Rock cutting

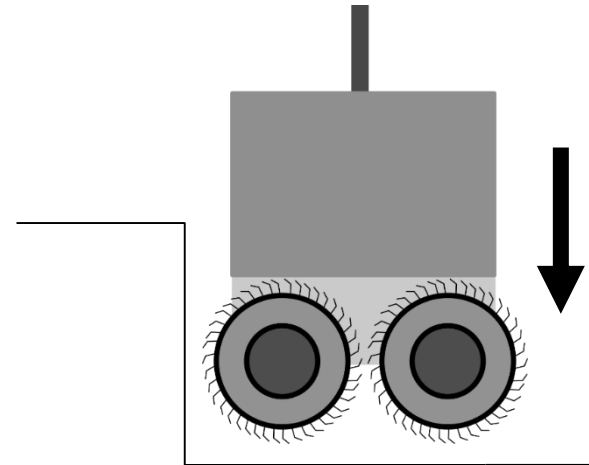


- Collecting/“re-cutting”



“Bauer Maschinen GmbH”

- Vertical Cutting



Seafloor Production Equipment/Rock Cutting

“Nautilus Minerals/SMD”

■ Disadvantages

- Sediment plume
- “layer by layer cutting”
- 3 machines required

■ Advantages

- Flexibility
- Partly active during down times

“Bauer Maschinen GmbH”

■ Disadvantages

- Subsea deployment/motion
- Potential down times (1 machine)

■ Advantages

- Low environmental impact
- Single machine system
- Independent from ore body thickness

Combination

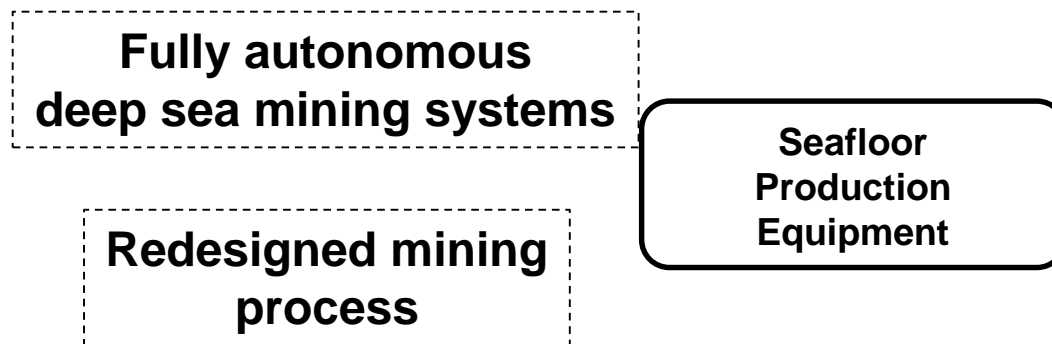
Seafloor Production Equipment/Nodules

Harvesting

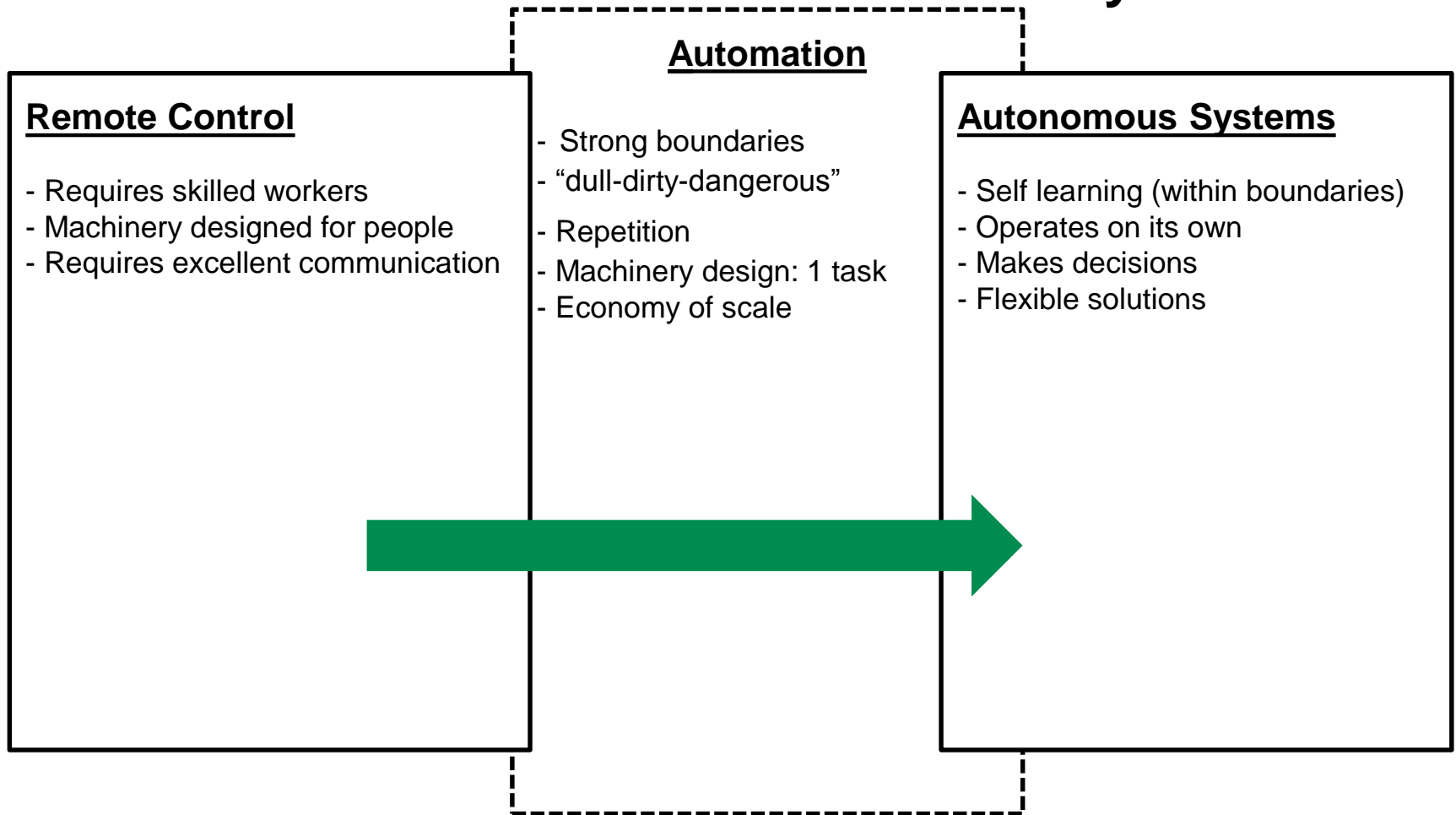


Design optimization

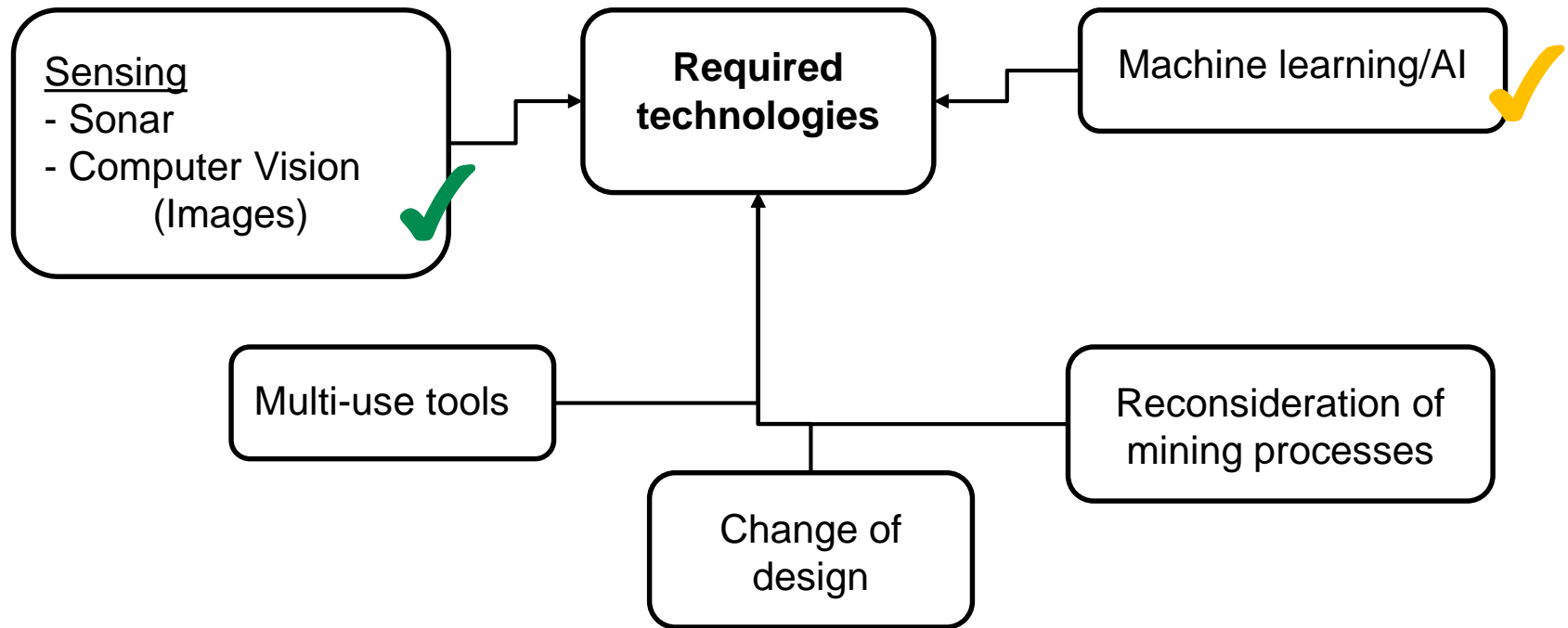
- Improved nodule recovery rate
- Less sediment disturbance



From Remote Control to Autonomous Systems



From Remote Control to Autonomous Systems



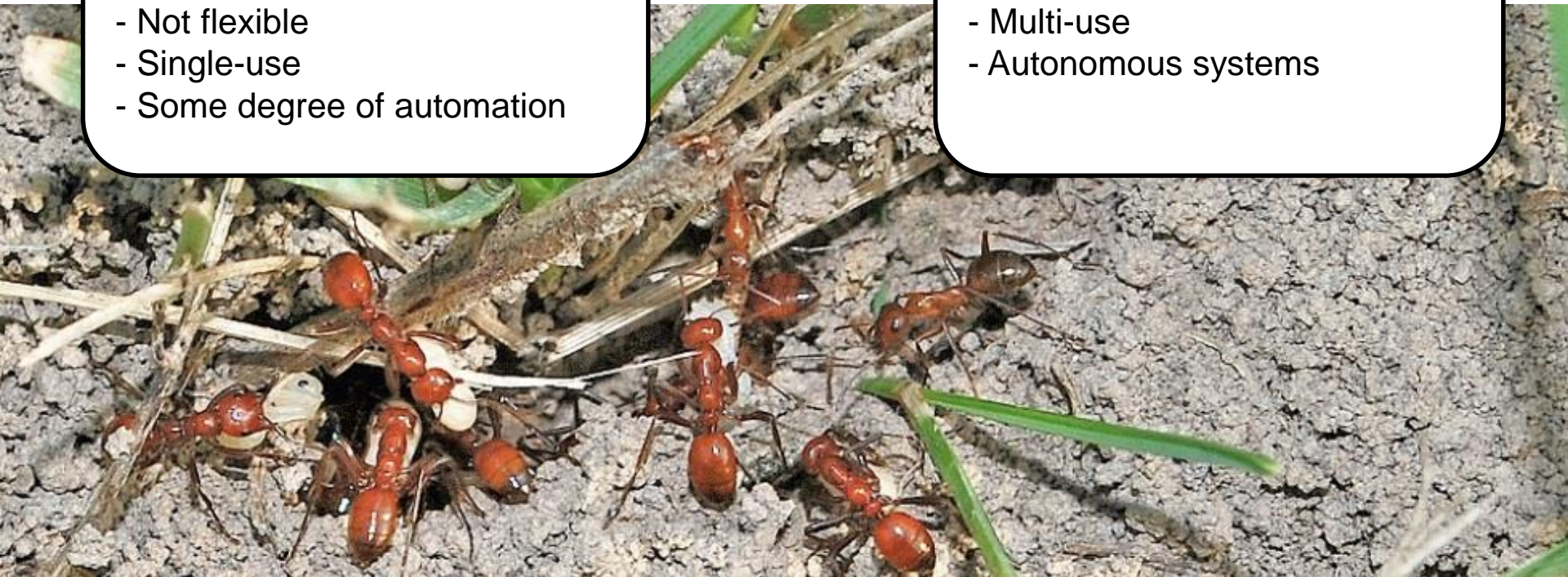
Towards New Mining Systems

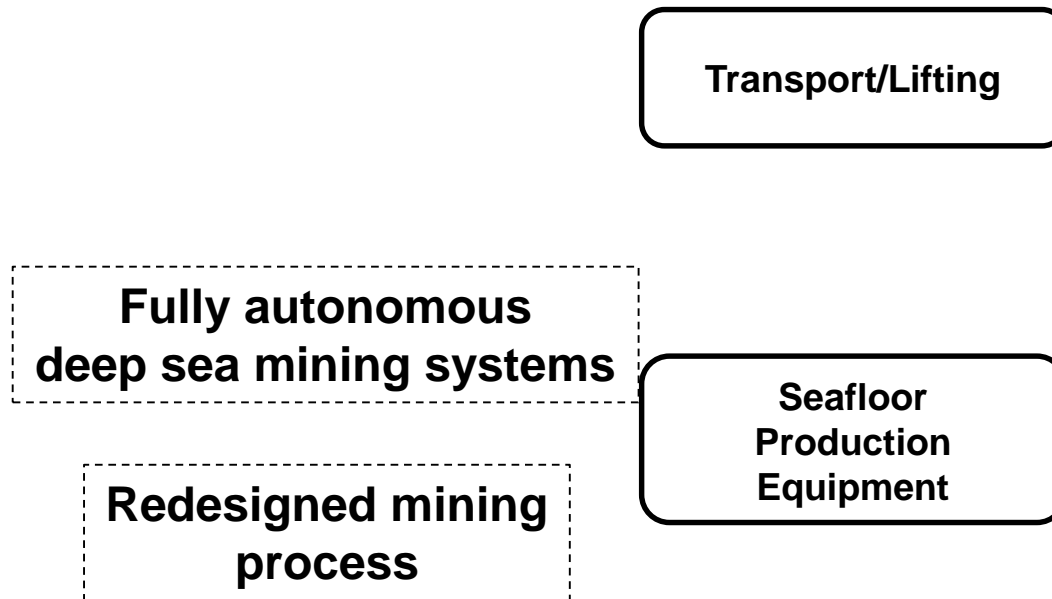
“traditional machinery”

- Big systems
- Economy of scale
- Not flexible
- Single-use
- Some degree of automation

Swarm robotics

- Small subsystems
- Very flexible
- Multi-use
- Autonomous systems

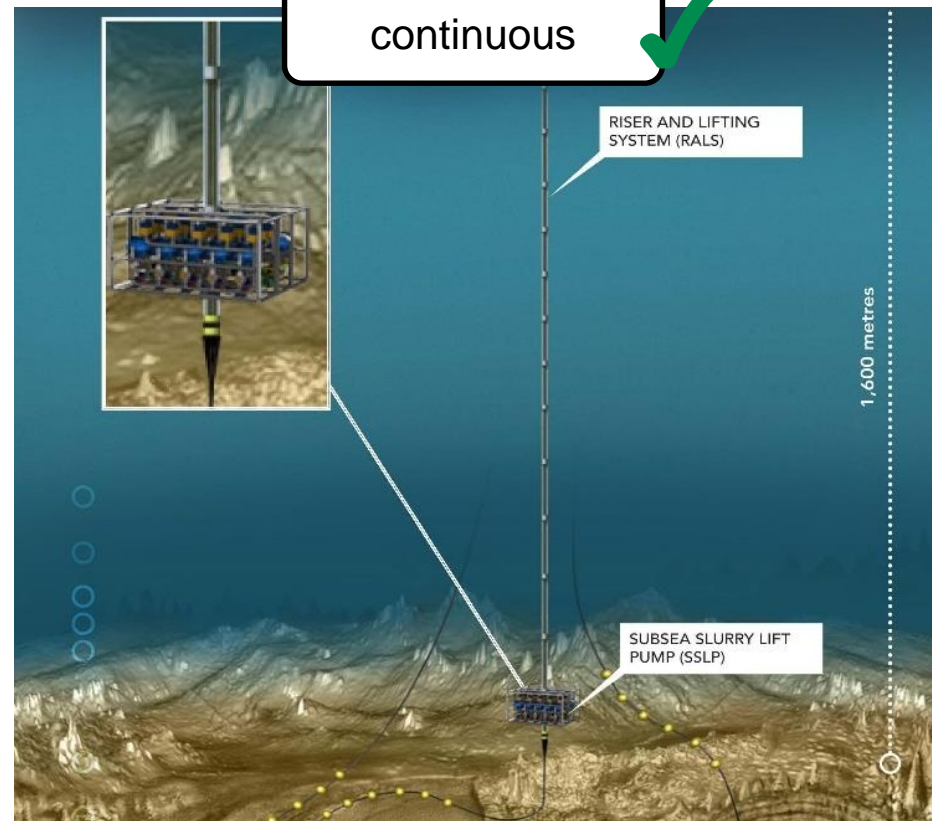


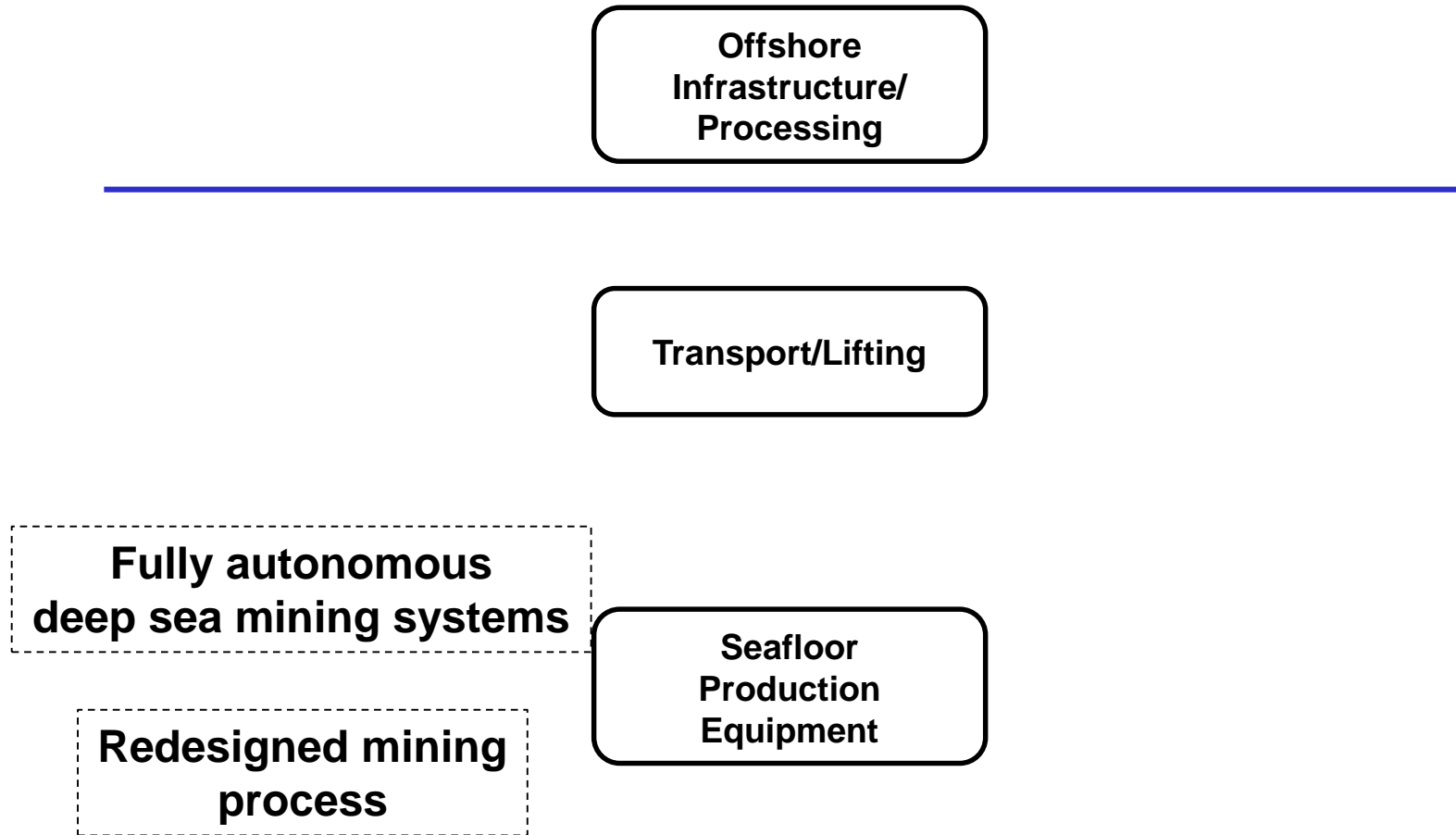


Transport/Lifting

discontinuous

continuous ✓





Zero-waste mining

**Offshore
Infrastructure/
Processing**

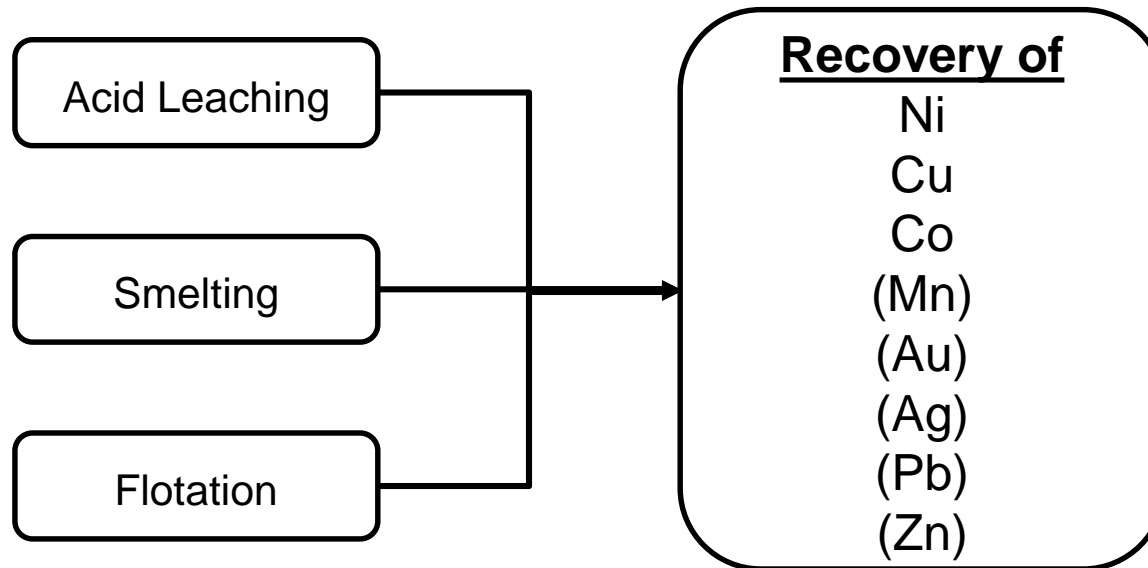
Transport/Lifting

**Fully autonomous
deep sea mining systems**

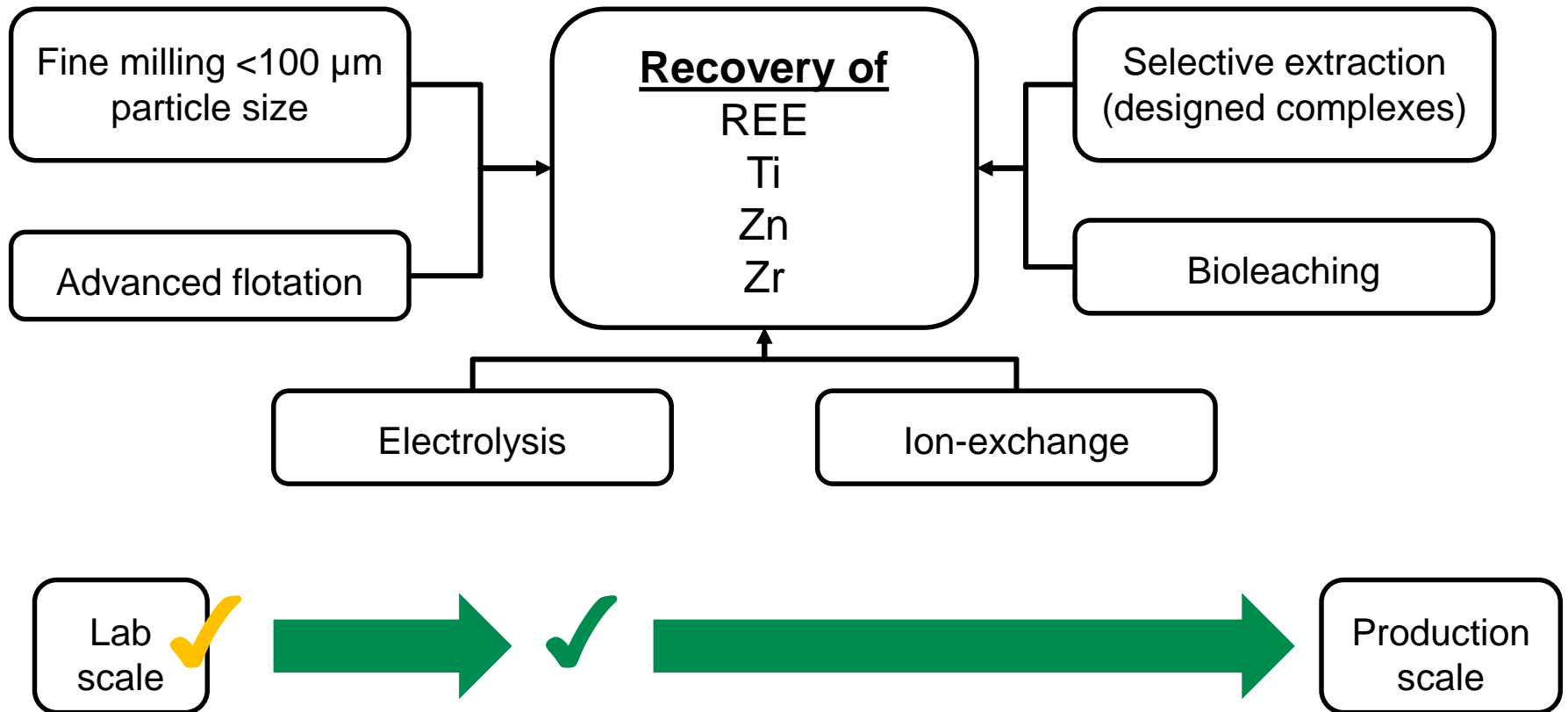
**Redesigned mining
process**

**Seafloor
Production
Equipment**

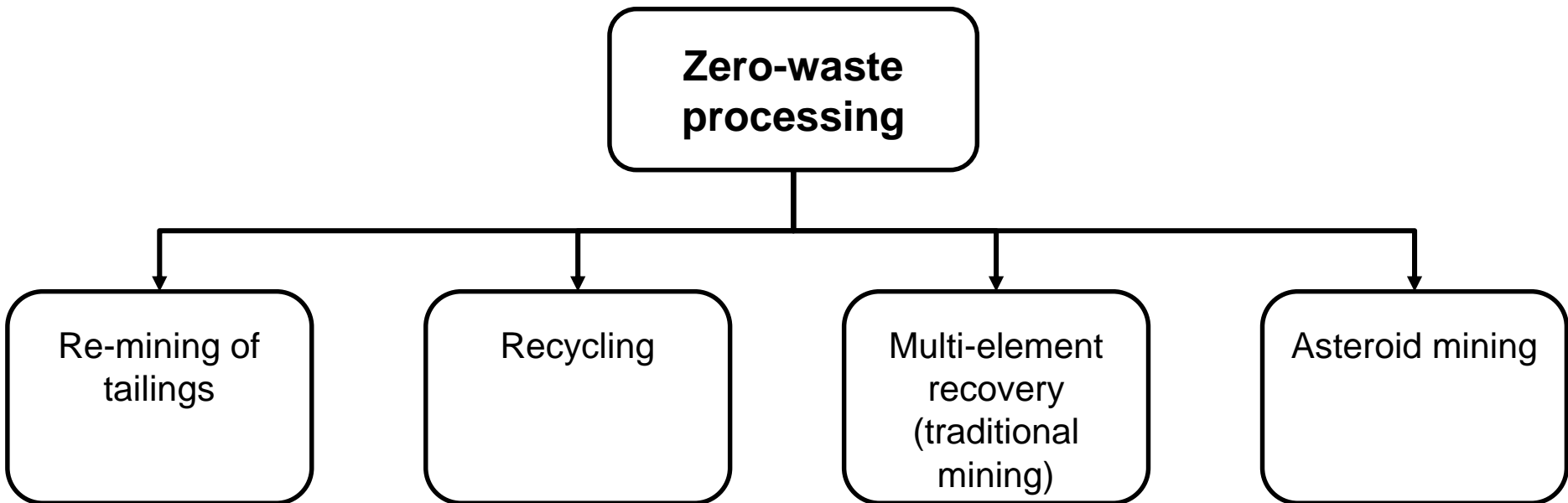
Processing

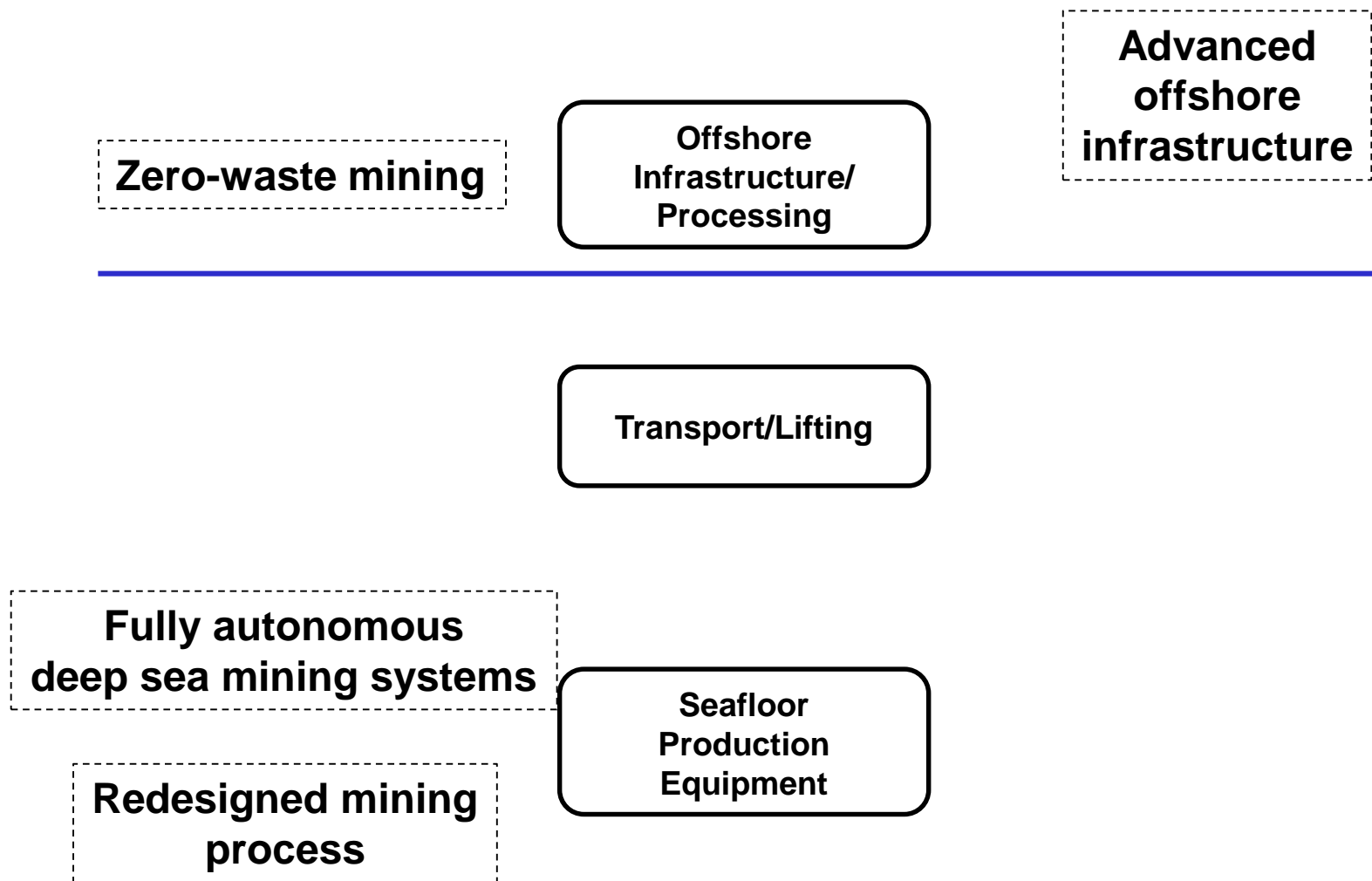


Processing/Zero-waste

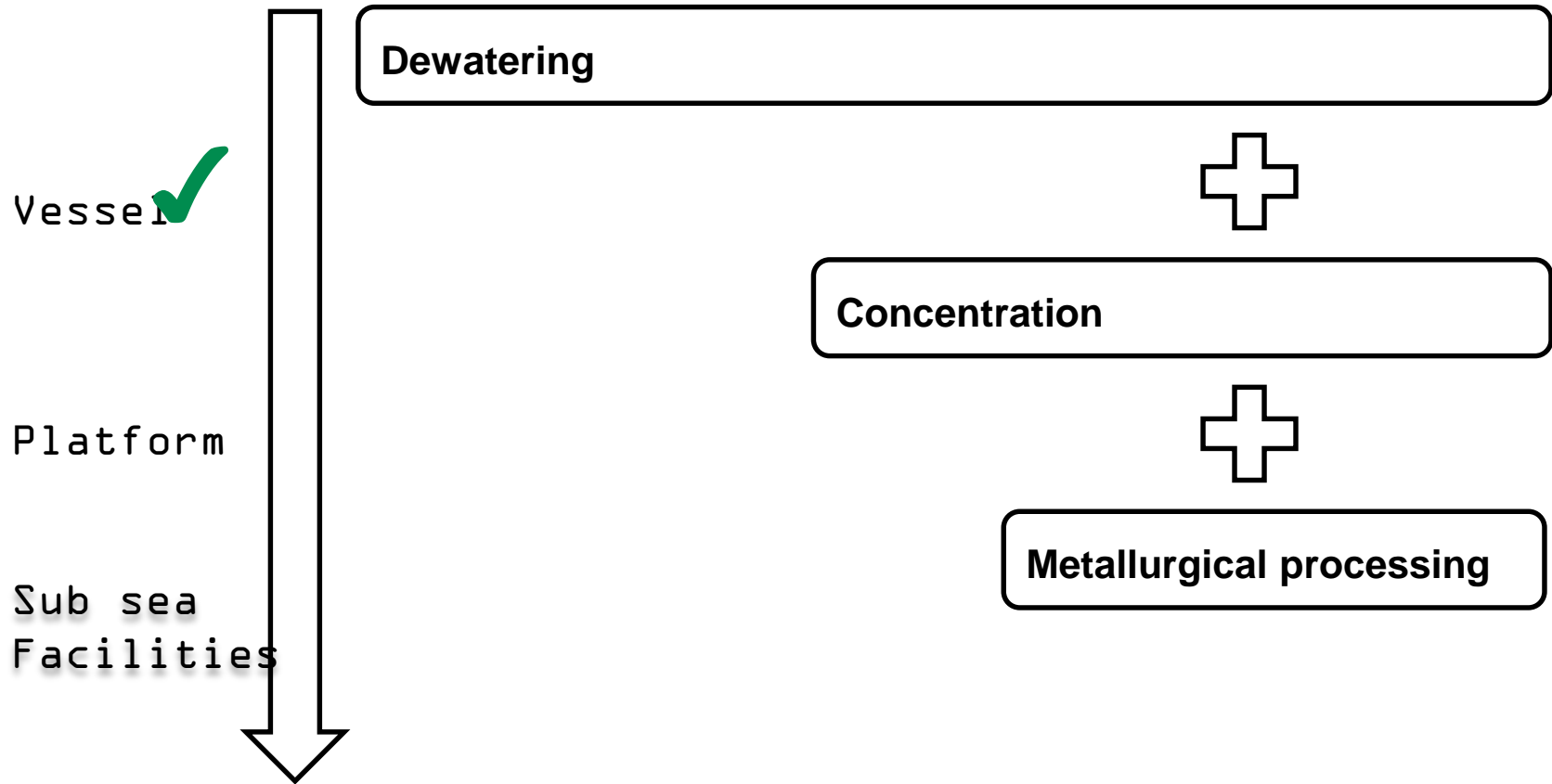


Processing/Zero-waste

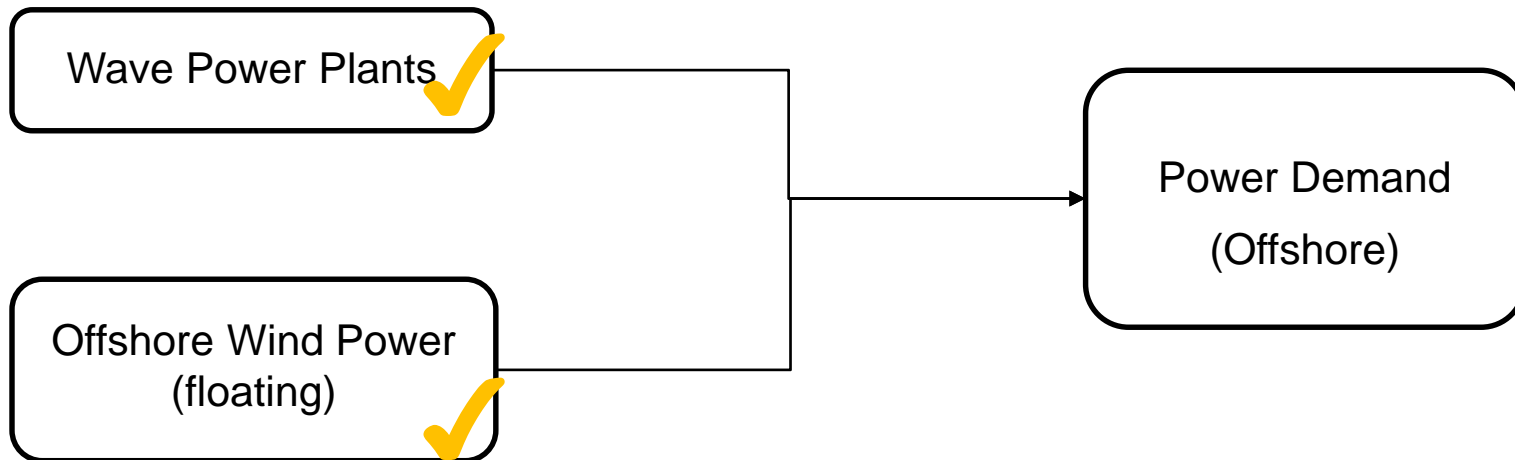




Offshore Infrastructure/Processing



Offshore Infrastructure



Zero-waste mining

**Offshore
Infrastructure/
Processing**

**Advanced
offshore
infrastructure**

Transport/Lifting

**Fully autonomous
deep sea mining systems**

**Redesigned mining
process**

**Seafloor
Production
Equipment**

**Minimum impact
mining operations**

Environmental Impact

Monitoring requirements

- What
- How
- When/How often
- Spatial extent



Impacts on mining projects

- Increased acceptance
- Adapting to adverse conditions

Multi-use

- Ocean exploration
- Monitoring of other maritime activities

Zero-waste mining

**Offshore
Infrastructure/
Processing**

**Advanced
offshore
infrastructure**

Transport/Lifting

**Fully autonomous
deep sea mining systems**

**Redesigned mining
process**

**Seafloor
Production
Equipment**

**Minimum impact
mining operations**

Image references

- Slide 2: <http://visibleearth.nasa.gov/view.php?id=73909>
- Slide 10: <https://commons.wikimedia.org/>
- Slide 12:
http://www.nautilusminerals.com/irm/content/images/technology_overview.jpg