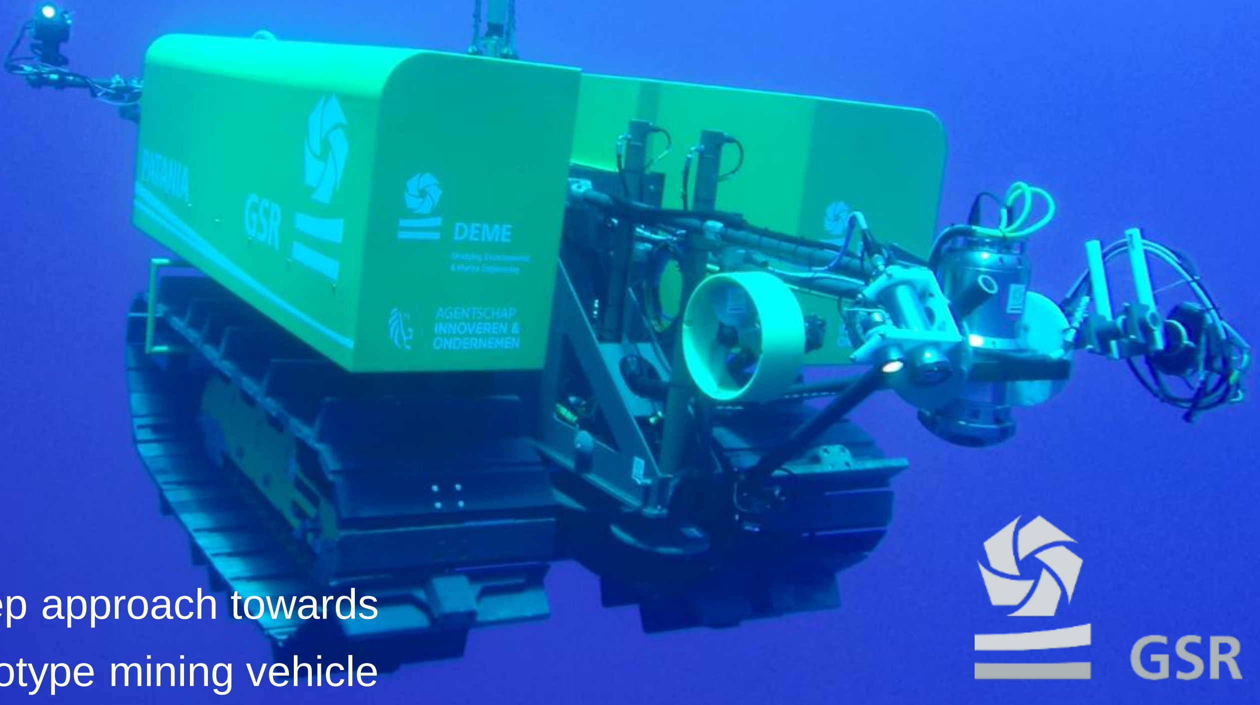
GSR's PROCAT-Project: Technical de-risking of deep sea mining equipment

Global Sea Mineral Resources

BGR, Hannover | 29.10.2018

Kris De Bruyne



A step-by-step approach towards a prototype mining vehicle

DEME
Dredging, Environmental & Marine Engineering

GSR

CONTENT OF THE PRESENTATION

CONOPS

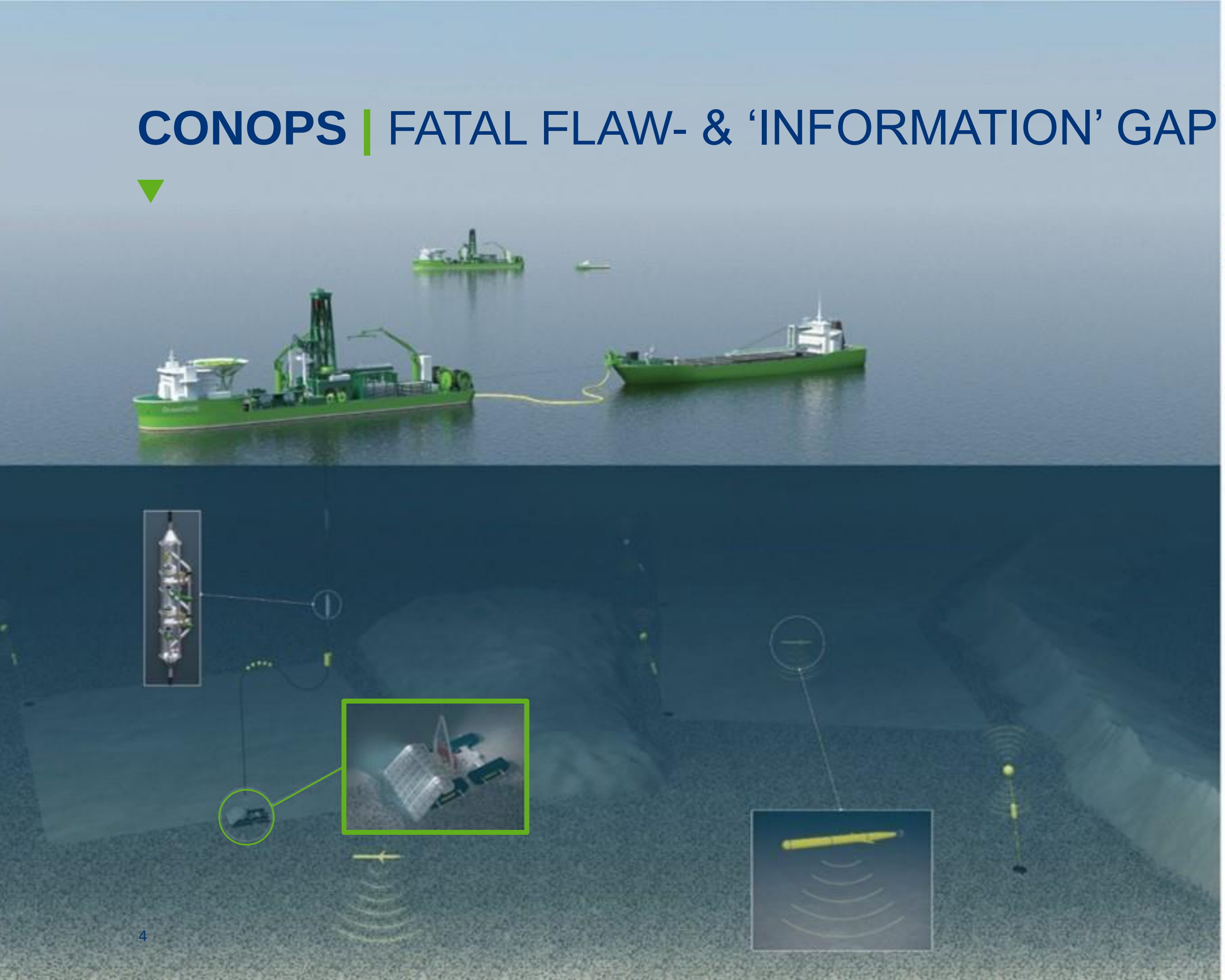
CONCEPT DESIGN CHOICE

PROCAT#1

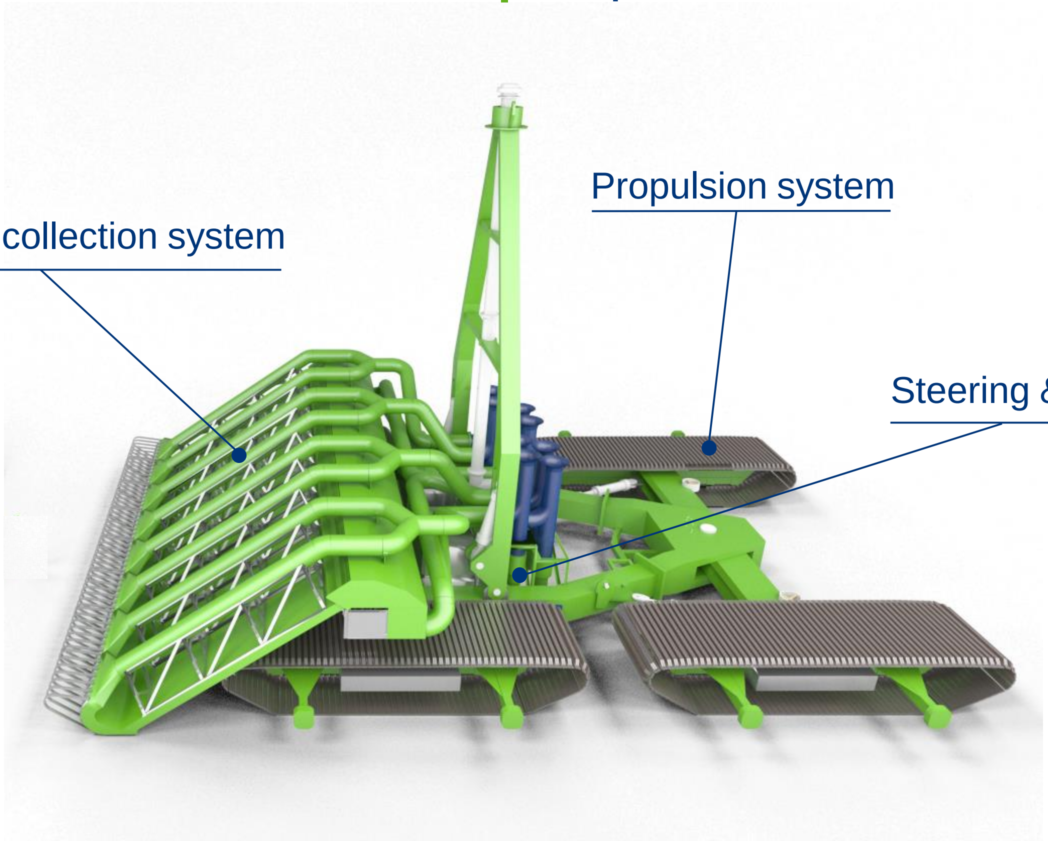
PROCAT#2

COMPASS

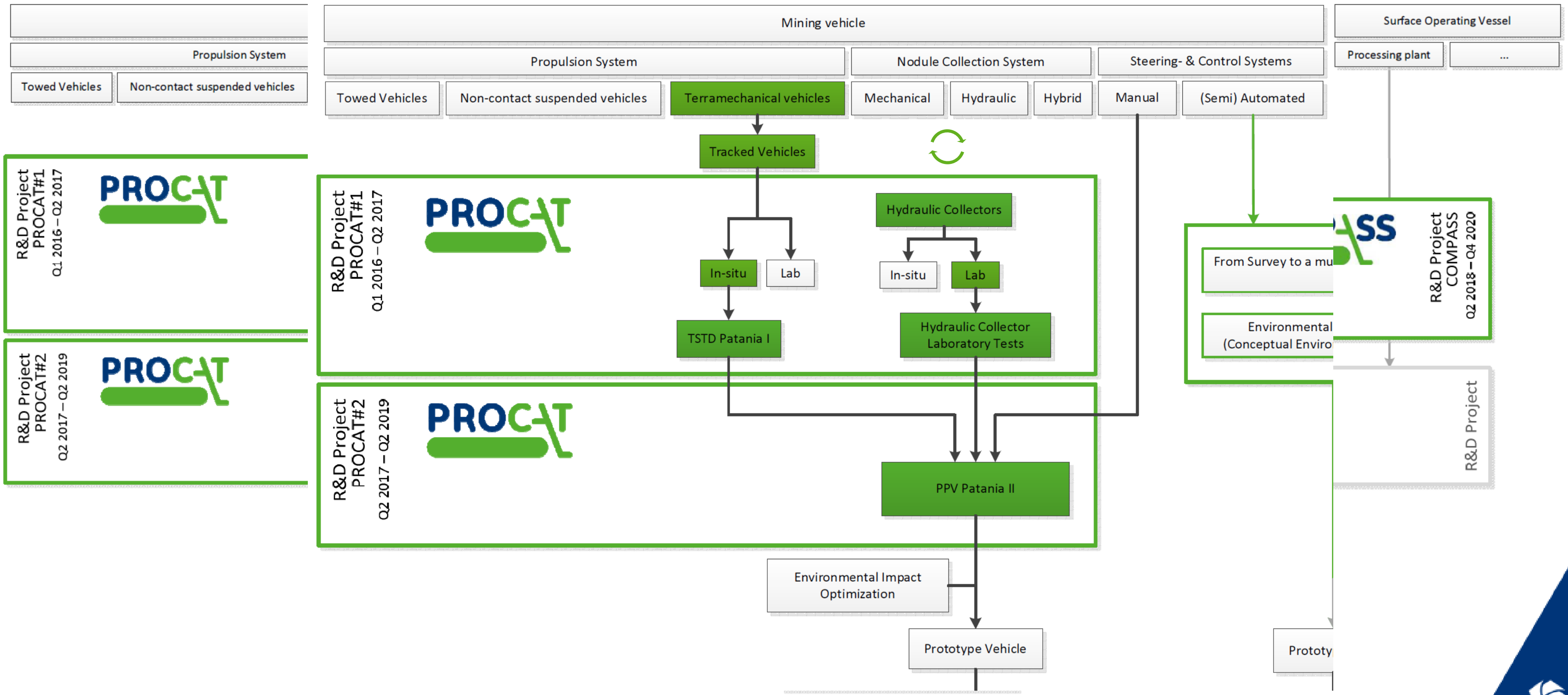
CONOPS | FATAL FLAW- & ‘INFORMATION’ GAP ANALYSIS



CONCEPT DESIGN CHOICE | Propulsion- & Collection system



CONCEPT DESIGN CHOICE | Propulsion- & Collection system



CONCEPT DESIGN CHOICE | Propulsion- & Collection system

- **Objective Nodule Collection System**: develop a collector head with an appropriate PRODUCTION CAPACITY with MINIMAL ENVIRONMENTAL IMPACT, OPTIMAL PICK-UP EFFICIENCY and MINIMAL DOWNTIME.
- **Step 1: Define Design Drivers:**
  - Production (X ton / year)
  - $\eta_{pick-up} = M_{pick-up}/M_{Total}$ (Maximal)
  - $\mathrm{Q_{water}}$ $(= Q_{pick-up} + Q_{separation}) \sim \mathrm{E_{total}}$
  - Environmental impact: ↓ ~ ↓ ~
    - *Turbidity:* $\sum T_{pick-up} + T_{separation} + T_{driving}$
    - *Seabed disturbance*
    - *Noise*
  - Seabed interaction
  - Reliability
  - Lifetime

CONCEPT DESIGN CHOICE | Propulsion- & Collection system

▶ **Step 2: Concept trade-off**

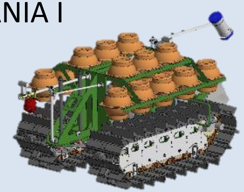
Design drivers		Hydraulic collectors >>	Mechanical collectors ("Scrapper" systems)
Pick-up efficiency	$\eta_{pick-up}$	? 100%	? (~100%)
Water flow	$Q_{pick-up}$	↑	≈ 0
	$Q_{separation}$	≈ 0 ~	↑
Environmental impact	$T_{pick-up}$	↑	↓ ~
	$T_{separation}$	↓	↑
	$T_{driving}$	=	=
	Seabed disturbance	Top layer fluidized	Top layer sliced off
	Noise	Water pumps	Water pumps + drive
Seafloor interaction	-	↓ (No direct interaction)	↑ (Direct interaction)
Reliability	-	↑	↓ (More moving parts)
Lifetime		?	

End product = Fluidized mixture

CONCEPT DESIGN CHOICE | Strategy

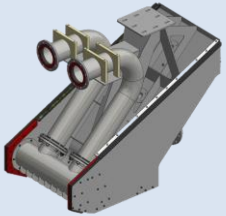
Step 1: Parallel collection- and trafficability study

TSTD PATANIA I



TRL 4

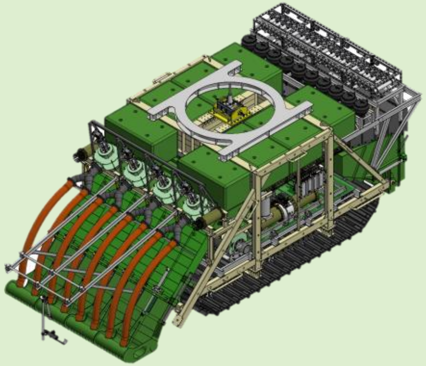
LAB TESTS



TRL 4

Step 2: In-situ integrated test of Pre-Prototype mining vehicle

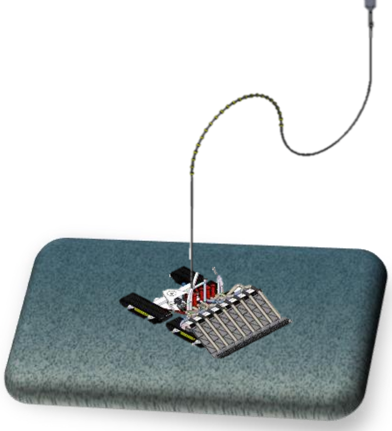
PPV PATANIA II



TRL 5 – In situ

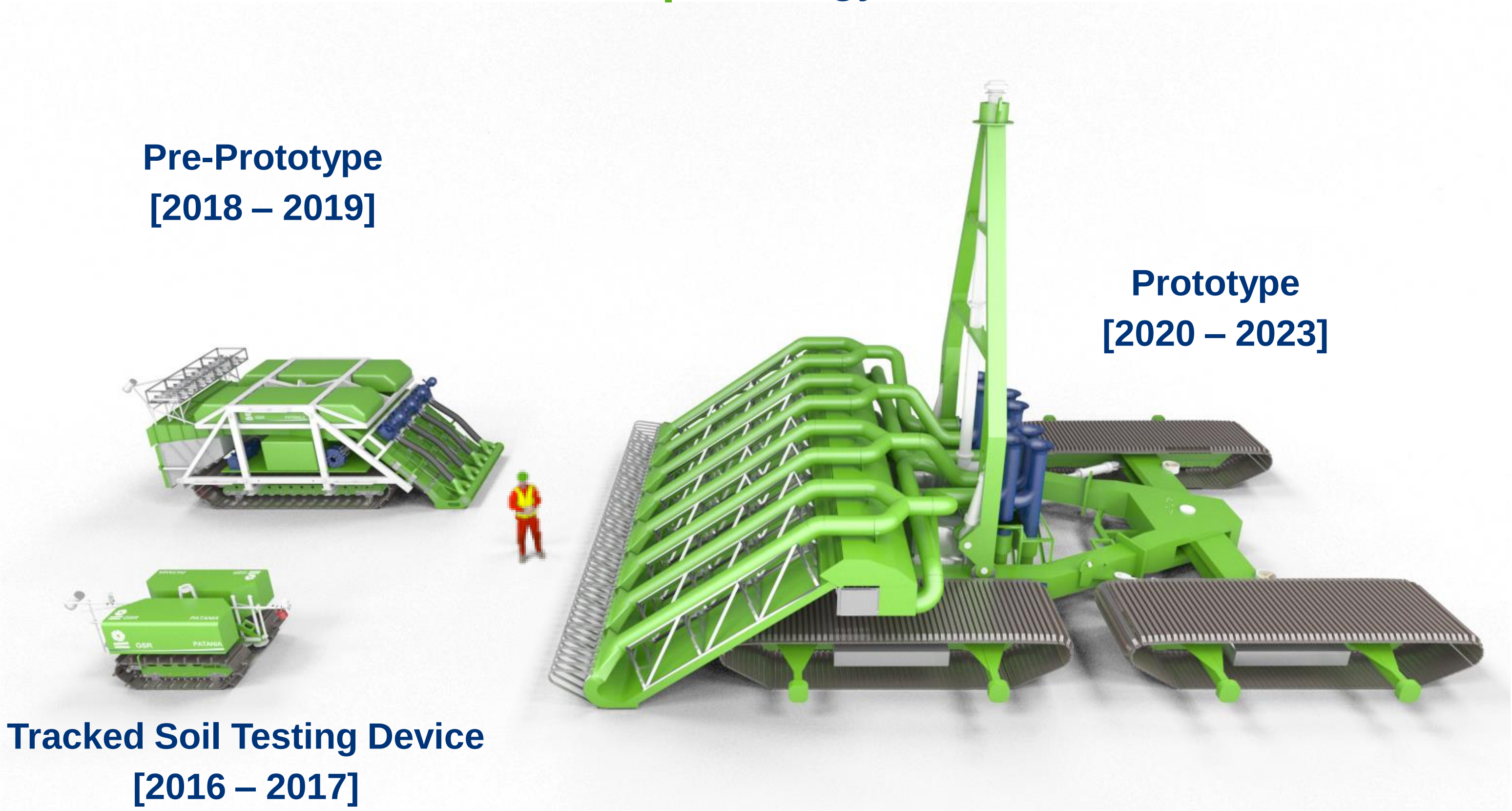
Step 3: In-situ System Integration Test

Vessel: Orion (DEME)
Start construction: 2016



Q1 2016 PROCAT Q2 2017 PROCAT Q2 2019 2022/2023

CONCEPT DESIGN CHOICE | Strategy



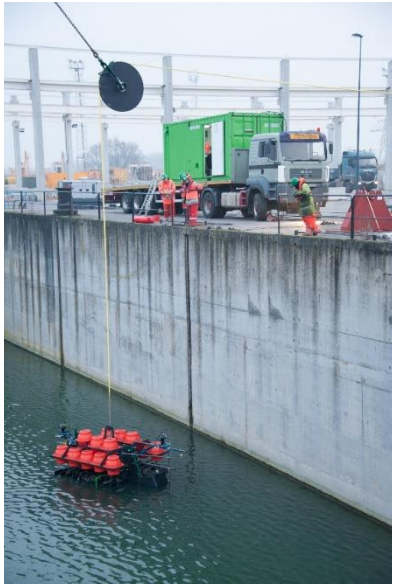
PROCAT#1 | TSTD PATANIA I & COLLECTOR LAB TESTS

“Until what depth will he not go?”

After the motto of Nicolas Fouquet (Superintendent of Finance of King Louis XIV) “Quo Non Ascendet”

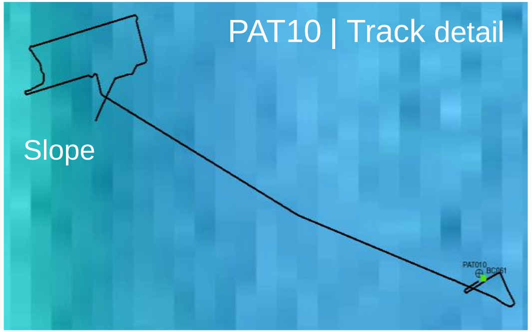
PROCAT#1 | Tracked Soil Testing Device PATANIA I

- **Objective:** Design and build a TRACKED UNDERCARRIAGE suitable to do RESEARCH ON TRACK PERFORMANCE on the sea bed at 4,700 m below sea level.



- General trafficability objectives:
  - Visual observation TSTD performance
  - Speed , acceleration & slope
- Terramechanical objectives:
  - Pressure – Sinkage relationship
  - Shear stress – shear strain relationship (ex-situ)
  - Thrust – slip relationship
- Environmental objectives:
  - Turbidity by tracks
  - Turbidity by horizontal water flow

PROCAT#1 | Tracked Soil Testing Device PATANIA I

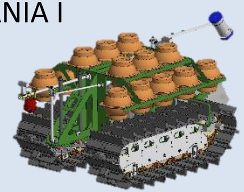


- 9 dives and 25 days before 1st success
- Maximum Depth: 4.571m
- Total distance: 14,5km
- 24 sets of Pressure – Sinkage tests
- 42 Shear Stress – Shear Displacement tests (ex-situ)
- 0 Thrust – slip measurements (failure on connectors anchor load cells)

CONCEPT DESIGN CHOICE | Strategy

Step 1: Parallel collection- and trafficability study

TSTD PATANIA I



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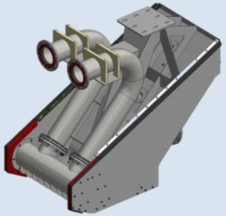

TRL 4

Step 2: In-situ integrated test of Pre-Prototype mining vehicle

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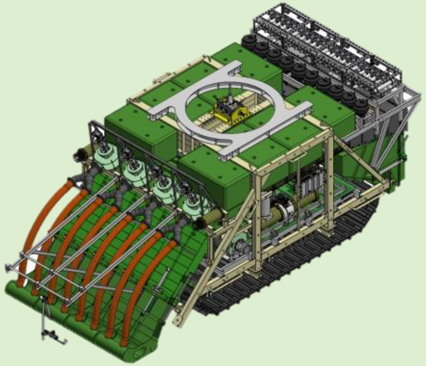

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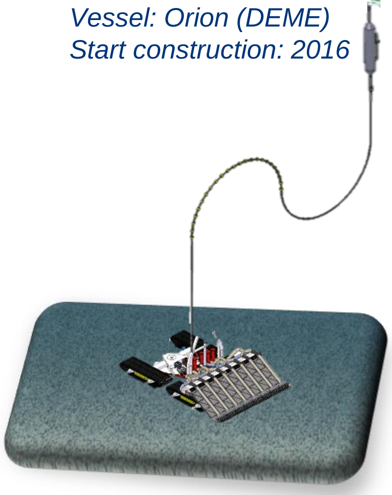


Q1 2016 — Q2 2017 — Q2 2019 — 2022/2023

PROCAT#1 | Nodule Collection Laboratory Tests

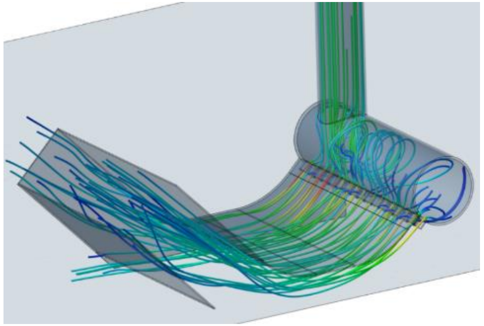
- **Objective:** develop a collector head with an appropriate PRODUCTION CAPACITY with MINIMAL ENVIRONMENTAL IMPACT, OPTIMAL PICK-UP EFFICIENCY and MINIMAL DOWNTIME.
- Definition:

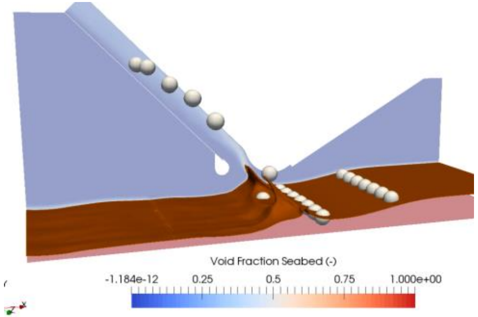
Hydraulic Nodule collector

Nodule Collector Head | Separation | Nodule mixture discharge

Sediment mixture discharge

- 2 parallel CFD programs:
  - Primary jet optimization (no nodules / sediment)
  - Pick-up process optimization (with nodules / sediment)





PROCAT#1 | Nodule Collection Laboratory Tests

- **Laboratory Tests:** trade off between REPRESENTATIVENESS and “TEST SETUP”-REALITY

- 70m test flume (33m effective test length)
- Artificial nodules (tumbled lava stones)
  - Nodule abundance 15 – 35 kg/m²
  - 3 different sizes
- Artificial sediment (diluted loam)
  - Loam vs. Clay vs. Bentonite
  - Disregarded top “fluffy” layer ($\downarrow T_{settling}$)
  - No “added” nodule penetration

PROCAT#1 | Nodule Collection Laboratory Tests

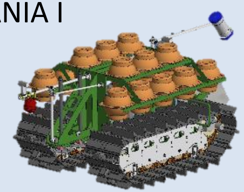
- **Test procedure: "**Per geometrical configuration, changing one control parameter at a time"
  - › 9 Geometrical configurations
  - › 4 Control parameters
    - Speed of the carriage - $v_{carriage}$
    - 2 x Jet velocity (v_{PU} and v_{TR})
    - Height above the testbed
- In total 85 test runs (3 months)
- Maximum pick-up efficiency: 99%

PROCAT#1 | Movie

CONCEPT DESIGN CHOICE | Strategy

Step 1: Parallel collection- and trafficability study

TSTD PATANIA I



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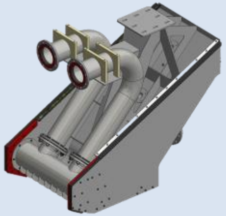
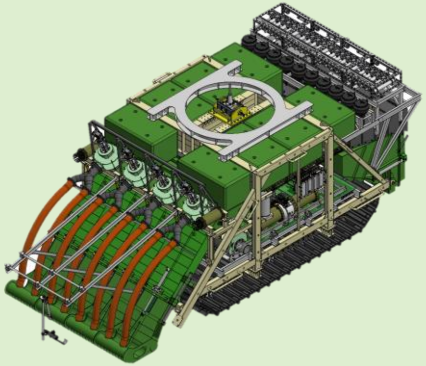


TRL 4

Step 2: In-situ integrated test of Pre-Prototype mining vehicle

PPV PATANIA II



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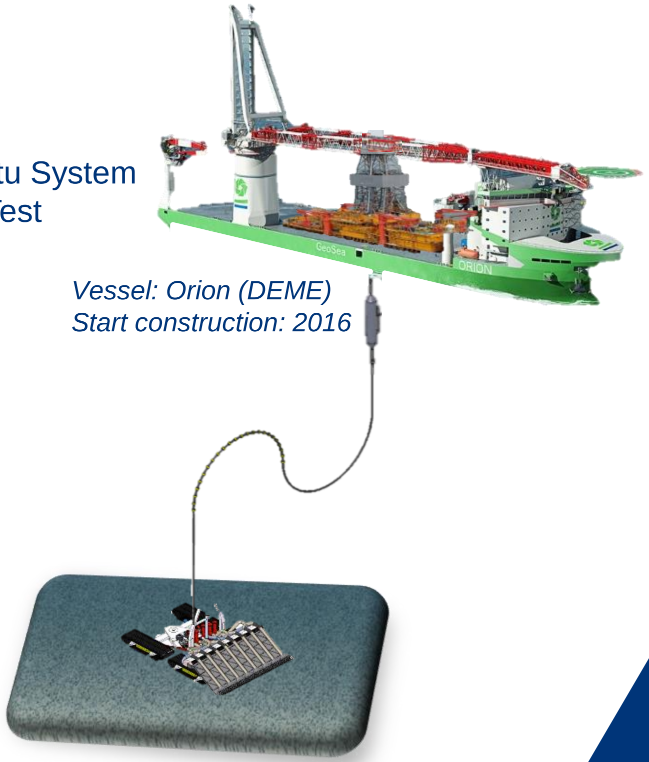
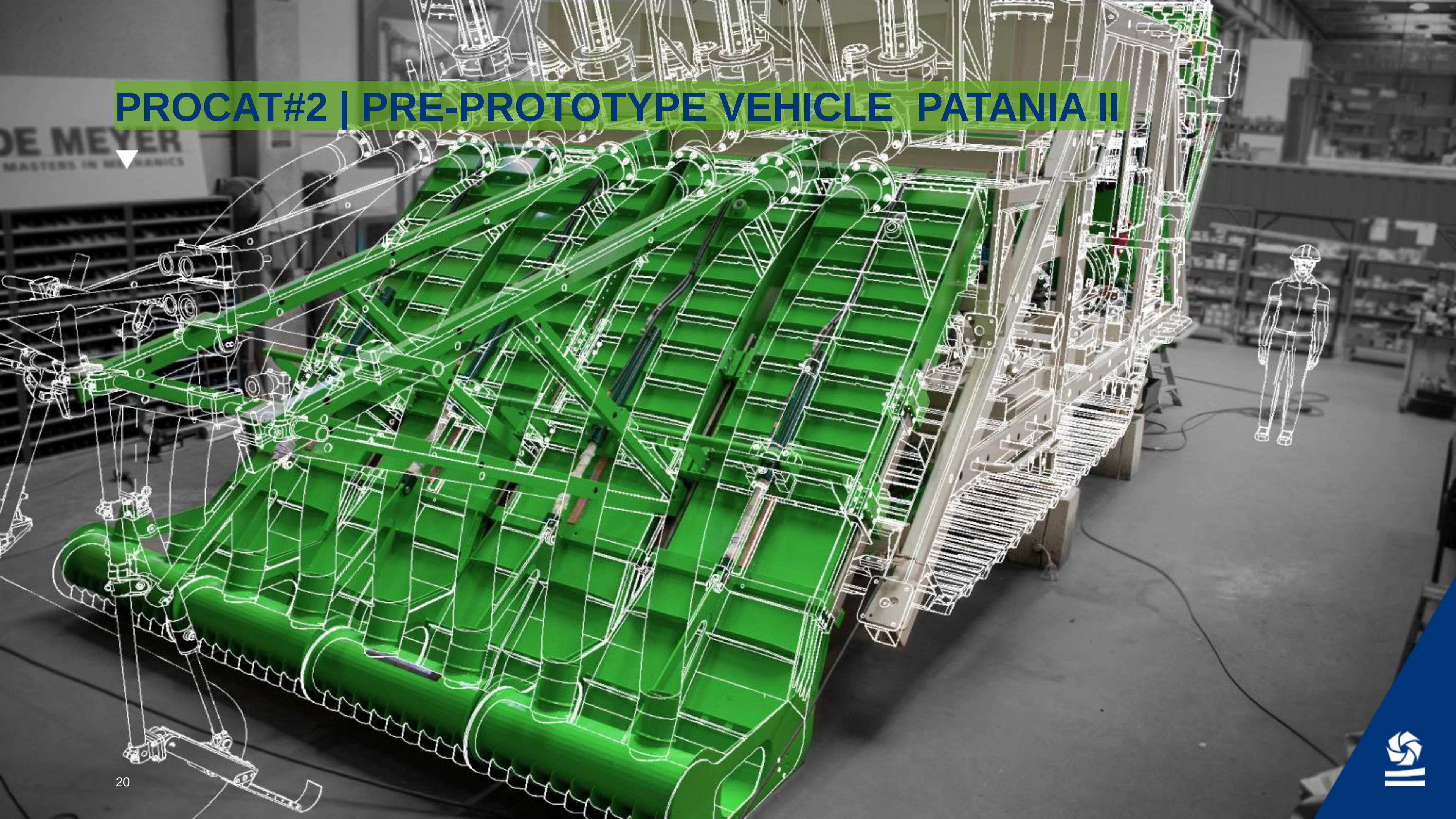


Q1 2016 — Q2 2017 — Q2 2019 — 2022/2023

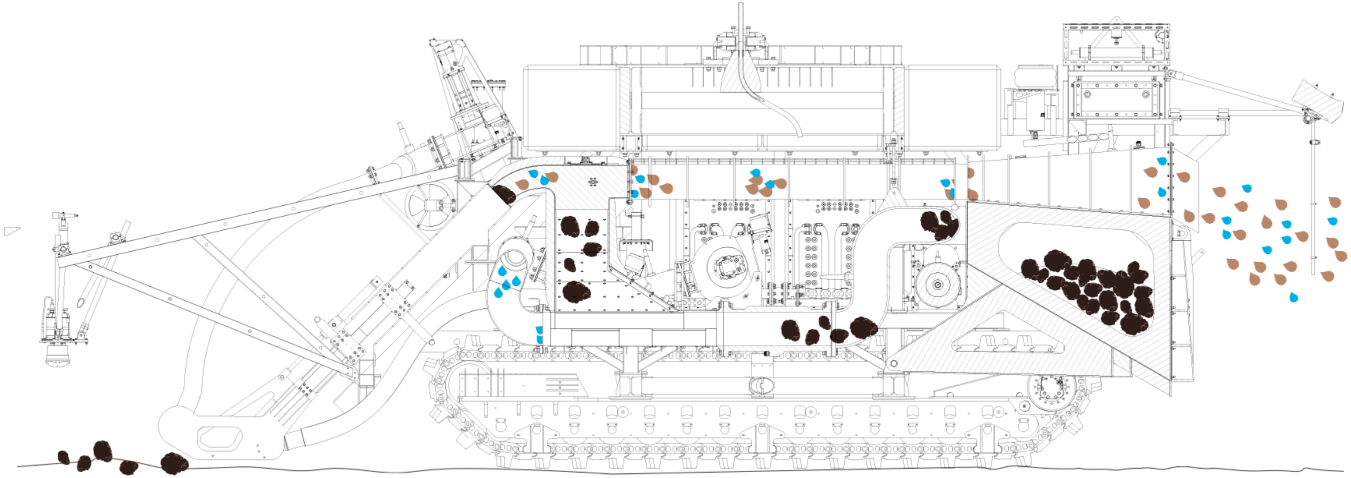
PROCAT#2 | PRE-PROTOTYPE VEHICLE PATANIA II



PROCAT#2 | INTEGRATED PRE-PROTYPE VEHICLE

- **Objective 1:** In-situ validation and optimization of the technology:
  - Nodule collection system ($\eta\% = f(v, H_{col}, Q_{jet}, \rho_{nod})$)
  - Trafficability (track performance, sinkage etc.)
  - Sensor suite (Multibeam, density meter etc.)
- **Objective 2:** Environmental impact experiments
  - Strip mining (mining impact experiment)
  - H_{col} vs. sediment pick-up
  - Mitigation systems (mudguards, diffusor etc.)
  - Input for hydrodynamic model (turbidity sensors)
- **Key Figures:**
  - Main Dimensions: L10m (+1m + 1m) x W4.7m x H4m
  - Mass: 35T.i.a. (incl. 3T payload nodules) ; 15T.s.
  - Total installed power: 400kW (4.2kV)

PROCAT#2 | INTEGRATED PRE-PROTYPE VEHICLE



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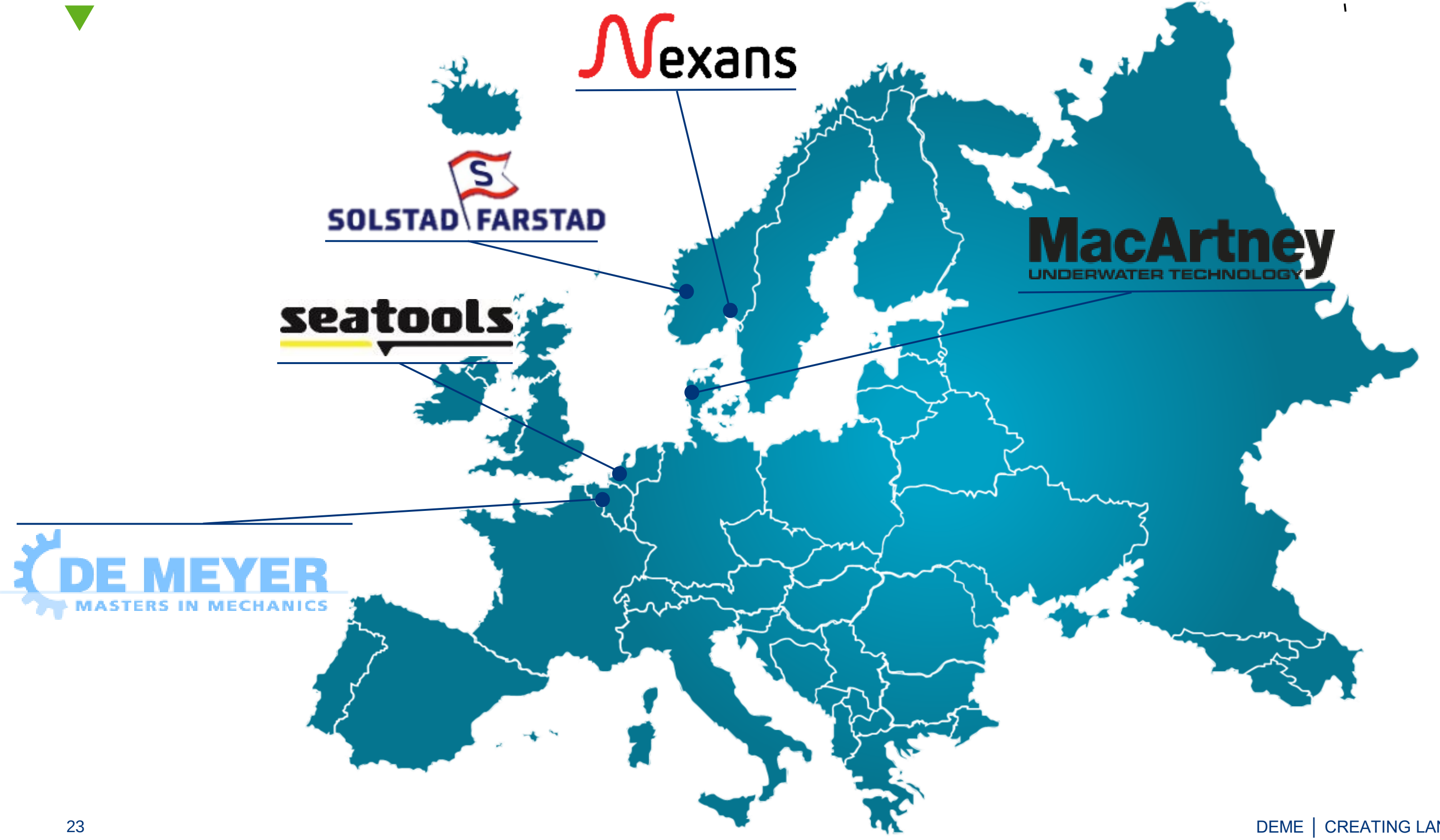


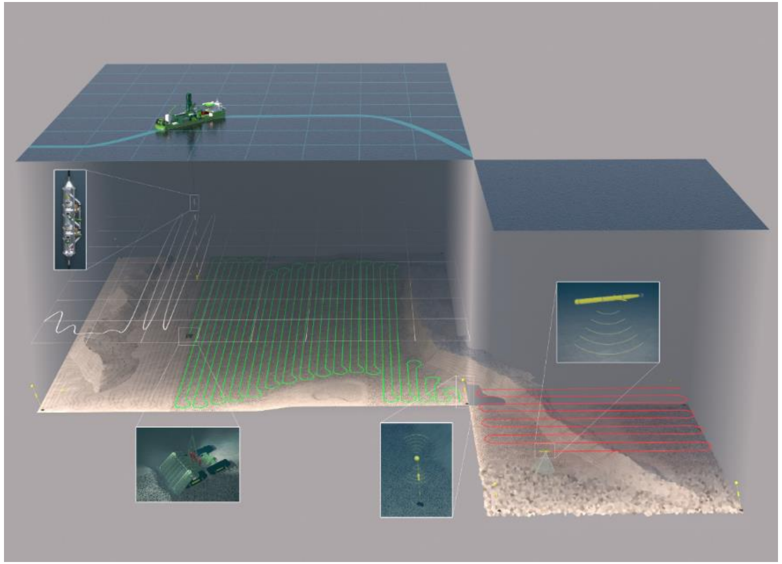
PROCAT#2 | INTEGRATED PRE-PROTYPE VEHICLE

- **Short term planning:**
  - Mob. (EU): December 2018
  - Tests (CCFZ): March - April 2019
- **Long Term Planning**
  - Legislation: 2020
  - System Integration test: 2022/23

COMPASS | ALGORITHM FOR AN OPTIMAL MINING PATH

COMPASS | ALGORITHM FOR AN OPTIMAL MINING PATH

- **COMPASS : Control of an Operational Mining Path through an Auto-adaptive Steering System**
  - Algorithm defining most optimal mining path
  - Technological challenges (System dynamics, technical limitations)
  - Environmental challenges (defining CEMS, Scale & Time)



Thank you for your attention

Questions?