A step-by-step approach towards a prototype mining vehicle
This presentation contains proprietary and/or confidential information. Any disclosure, copying, distribution or use of this information/the ideas incorporated is strictly prohibited. This information is not to be considered as a representation of any kind. Any intellectual and industrial property rights and any copyrights with regard to this presentation, and the information therein, shall remain the sole property of DEME.
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

- Nodule collection system
- Propulsion system
- Steering & control 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)
  - \( \eta_{\text{pick-up}} = \frac{M_{\text{pick-up}}}{M_{\text{Total}}} \) (Maximal)
  - \( \dot{Q}_{\text{water}} = \dot{Q}_{\text{pick-up}} + \dot{Q}_{\text{separation}} \sim E_{\text{total}} \)
  - Environmental impact:
    - Turbidity: \( \sum T_{\text{pick-up}} + T_{\text{separation}} + T_{\text{driving}} \)
    - Seabed disturbance
    - Noise
  - Seabed interaction
  - Reliability
  - Lifetime
**CONCEPT DESIGN CHOICE | Propulsion- & Collection system**

### Step 2: Concept trade-off

<table>
<thead>
<tr>
<th>Design drivers</th>
<th>Hydraulic collectors</th>
<th>Mechanical collectors (“Scraper” systems)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick-up efficiency</td>
<td>$\eta_{pick-up}$</td>
<td>? 100%</td>
</tr>
<tr>
<td>Water flow</td>
<td>$Q_{pick-up}$</td>
<td>$\uparrow$</td>
</tr>
<tr>
<td></td>
<td>$Q_{separation}$</td>
<td>≈ 0 ~</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>$T_{pick-up}$</td>
<td>$\uparrow$</td>
</tr>
<tr>
<td></td>
<td>$T_{separation}$</td>
<td>$\downarrow$</td>
</tr>
<tr>
<td></td>
<td>$T_{driving}$</td>
<td>=</td>
</tr>
<tr>
<td>Seabed disturbance</td>
<td>Top layer fluidized</td>
<td>Top layer sliced off</td>
</tr>
<tr>
<td>Noise</td>
<td>Water pumps</td>
<td>Water pumps + drive</td>
</tr>
<tr>
<td>Seafloor interaction</td>
<td>-</td>
<td>↓ (No direct interaction)</td>
</tr>
<tr>
<td>Reliability</td>
<td>-</td>
<td>↑</td>
</tr>
<tr>
<td>Lifetime</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

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
Q2 2017
Q2 2019
2022/2023
CONCEPT DESIGN CHOICE | Strategy

Pre-Prototype [2018 – 2019]

Prototype [2020 – 2023]

Tracked Soil Testing Device [2016 – 2017]
“Until what depth will he not go?”

After the motto of Nicolas Fouquet (Superintendent of Finance of King Louis XIV) “Quo Non Ascendet”
**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
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
Q2 2017
Q2 2019
2022/2023
**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)
**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 (↓ $T_{settling}$)
  - 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 - \( v_{\text{carriage}} \)
    - 2 x Jet velocity (\( v_{\text{PU}} \) and \( v_{\text{TR}} \))
    - 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
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 Q2 2017 Q2 2019 2022/2023
PROCAT#2 | INTEGRATED PRE-PROTOTYPE 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-PROTOTYPE VEHICLE
PROCATE2 | INTEGRATED PRE-PROTOTYPE VEHICLE

Nexans

SOLSTAD FARSTAD

seatools

MacArtney

DE MEYER

MASTERS IN MECHANICS
PROCESS #2 | INTEGRATED PRE-PROTOTYPE 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?