

# CAGE

**Composite casing and the Acceleration of  
Geothermal Energy**



# CAGE-project

The CAGE-project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731117



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# A project from:

- Huisman Well Technology (NL)
- Mijwater (NL)
- Radial Drilling Europe (NL)
- VITO (B)
- Thomas More Kempen (B)
- GZB – Fraunhofer (D)

# Work packages & tasks:

- WP 1: preparatory studies
- WP 2: development of full-composite mechanical connection
- WP 3: demonstration of shallow GE concept & new technology
- WP 4: Management, Coordination & Dissemination



# CAGE work packages & tasks:

## WP 1: Preparatory studies:

### WP 1.1: Road Map with high-potential areas (Thomas More Kempen)

*Task 1.1.1: feasibility of geothermal and HT heat storage for low temperature heating (TMK)*

*Task 1.1.2: geothermal energy potential, high-potential areas & heat demand (TMK)*

### WP 1.2: Geology & flow-modelling (VITO)

*Task 1.2.1: thermal output of multi-radial well targeting Cretaceous chalks (VITO)*

*Task 1.2.2: assessment of costs for a geothermal / HT-storage system targeting Cretaceous chalks (VITO)*

### WP 1.3: DML: Digital Mud Logging System (HWT)

*Task 1.3.1: final design digital mud logger*

*Task 1.3.2: manufacture test set-up of digital mud logger*

*Task 1.3.3: software development data processing (cuttings: carbonate, clay, sand, other...)*

### WP 1.4: Laboratory Acoustic Multi Sensoric Process Analysis testing (GZB / Fraunhofer)

*Task 1.4.1: analyse and fine-tune the I/O data and determine a usable bandwidth of parameters*

*Task 1.4.2: determine the type of sensors being required in order to record pertinent data*

*Task 1.4.3: monitor the drill string / jet / coil response and analyse its output / response signals*

*Task 1.4.4: perform test program with autoclave system iBOGS with MOUSE*

*Task 1.4.5: development of an appropriate MWjet online monitoring tool*

## CAGE work packages & tasks:

### WP 1: Preparatory studies (continued):

#### WP 1.5: Enhanced Radial Jet Drilling (RDE)

*Task 1.5.1: desk-study of performed Radial Jet Drilling operations (Geothermal and Oil & Gas)*

*Task 1.5.2: analysis of cores and cuttings in VITO (Balmatt) and Wayland area*

*Task 1.5.3: risk analysis Enhanced Radial Jet Drilling operations*

*Task 1.5.4: laboratory testing of rock samples corresponding to VITO and Wayland geology*

#### WP 1.6: Well design (Mijnwater & third party Well Engineering Partners)

*Task 1.6.1: determining the optimal well location(s)*

*Task 1.6.2: final well design(s)*

### WP 2: Development of full-composite mechanical connection (HWT)

#### WP 2.1: Development phase

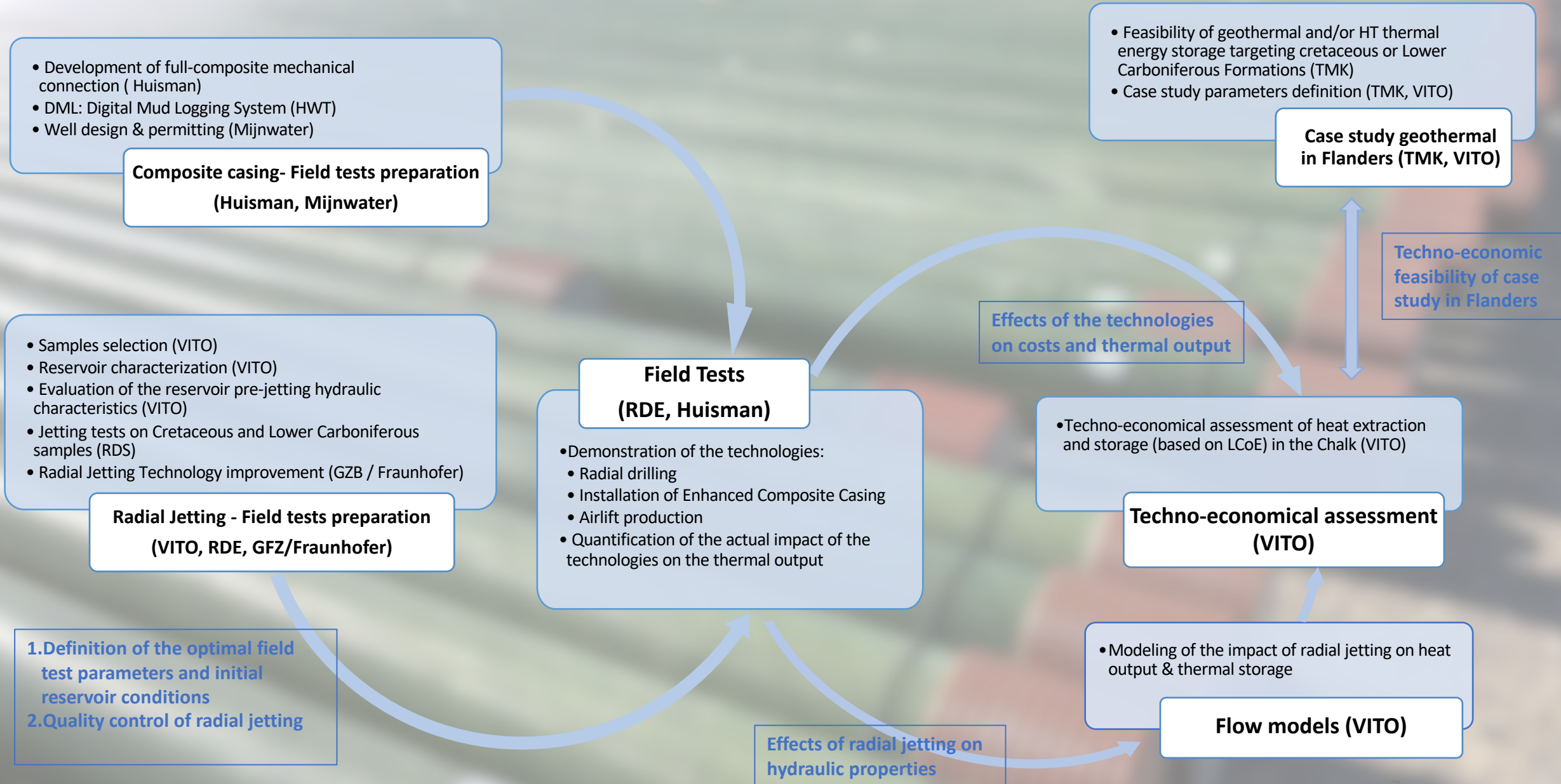
#### WP 2.2: HSCC mechanical connection - test phase

#### WP 2.3: HSCC Acceptance Program, focussed on mechanical connection

### WP 3: Demonstration of shallow GE concept & new technology → Not yet started

### WP 4: Management, Coordination & Dissemination

# Workflow and collaboration between partners





# WP 1.1: Road Map with high-potential areas

## WP 1: Preparatory studies:

### WP 1.1: Road Map with high-potential areas (Thomas More Kempen)

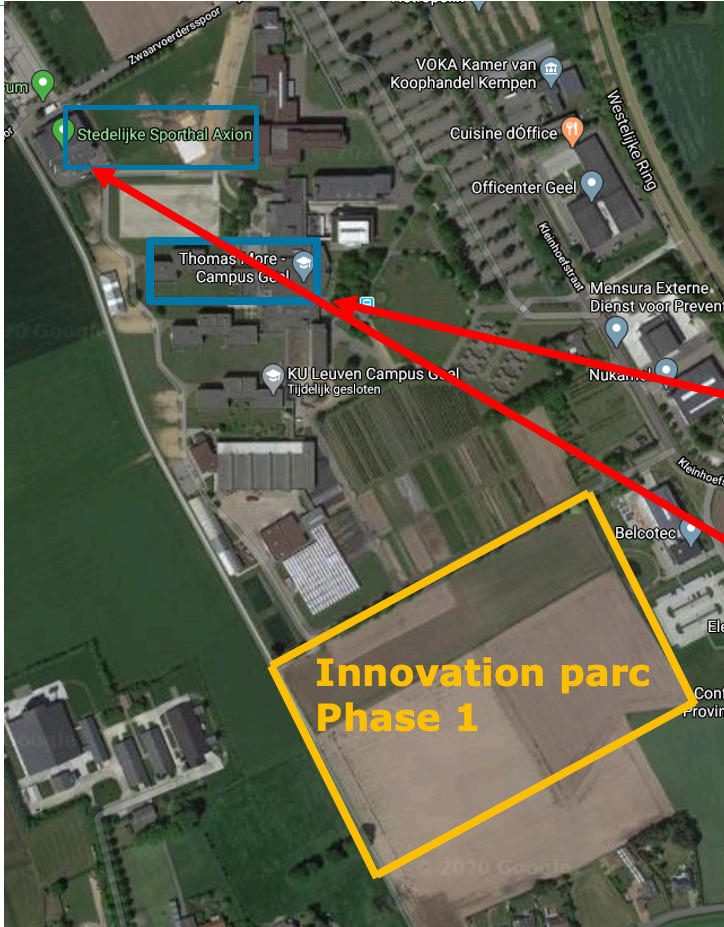
*Task 1.1.1: feasibility of geothermal and HT heat storage for low temperature heating (TMK)*

*Task 1.1.2: geothermal energy potential, high-potential areas & heat demand (TMK)*

# CASE STUDY GEOTHERMICA - CAGE

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Knowledge centre Energy  
(University Thomas More – Geel/Belgium)  
25/06/2020

# SITUATION



## Belgium – GEEL – University Thomas More

Heading Degree Days : 2200 (base 16,5 °c)

Existing building :

- University Thomas More
  - Energy Demand : 4450 MWh/yr
  - Heat demand : 2410 kW
- Sport location (AXION 1)
  - Energy demand : 379 MWh/yr
  - Heat demand : 210 kW



# EXPANSION

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## Expansion with :

### **1. Innovation Parc**

- Office : 35.000 m<sup>2</sup>
- Storage : 7.500 m<sup>2</sup>
- Heat demand
  - 40 W/m<sup>2</sup> for offices means 1400 kW
  - 60 W/m<sup>2</sup> for storage means 450 kW
  - TOTAL HEAT DEMAND : 1850 kW
  - Total energy use : 2200 MWh/yr

### **2. New sport location : AXION 2 (same as AXION 1 and build next axion 1)**

- Energy demand : 379 MWh/yr
- Heat demand : 210 kW

# EXCERCICE

Take a look at the possibilities for using geothermal energy in combination with a heat network.

What is the best place for location collector

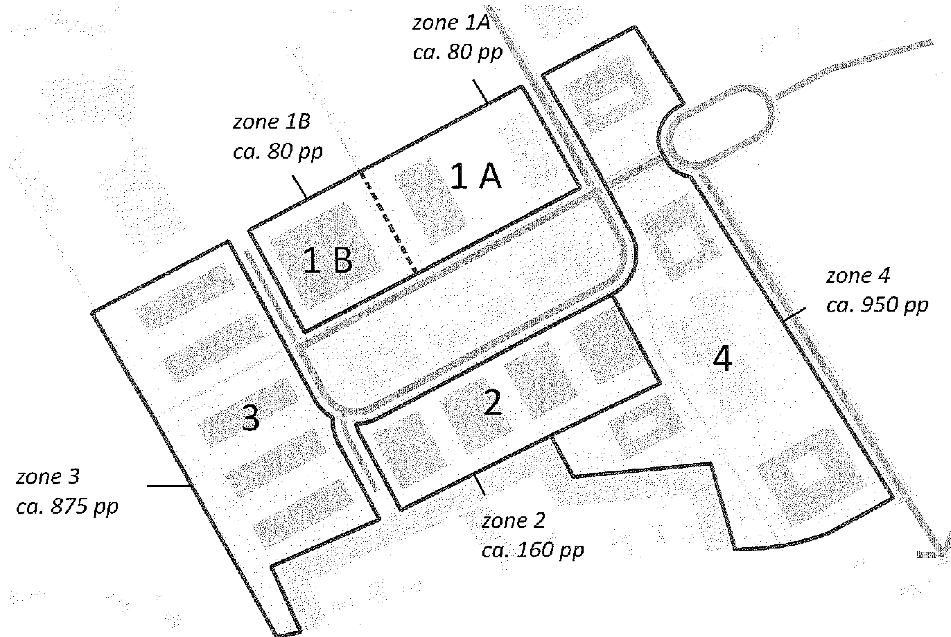


Figure : Division of Innovation Park into different zones/functions

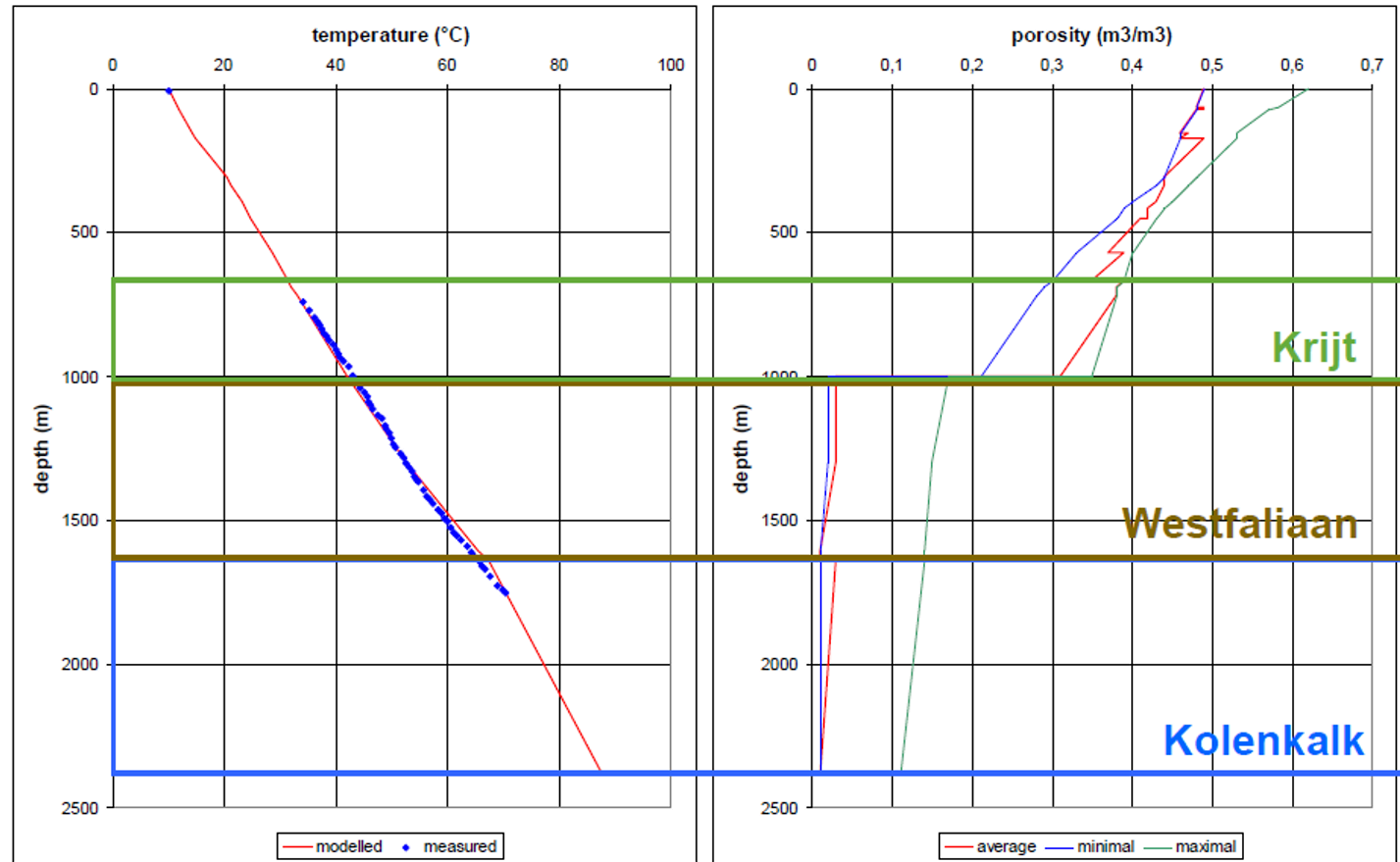


Collector)

Simulation innovation parc



# GEO THERMAL RESERVOIRS (REGION KEMPEN)



Bron : VITO

# POSSIBILITY

	Krijt	Onder-Carboon
Supply Temperature	35° C	95° C
Injection Temperature	22° C	60° C
Production flow	75 m³/h	125 m³/h
Heat Power	1125 kW	5100 kW
Heat energy	4000 MWh (3555 h)	7050 MWh
Power pump	90 kW	190 kW
Total volume	263700 m³/y	172700 m³/j

BRON : VITO

# POSSIBILITY INNOVATION PARC + THOMAS MORE

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- Only Innovation Parc :
  - Heat demand : 1850 kW
    - Krijt : 2 drillings 1000 m
    - Onder-carboon 1 drilling
- Innovation Parc + Thomas More + Axion (sport)
  - Heat demand : 4680 kW
    - Krijt : 4 à 5 drillings 1000 m (expensive )
    - Onder-carboon 1 drilling

# RESULTS USING THERMOS

Heat demand	4680 kW
Energy demand	7408 MWH
Pipe length	3,8 km
Pipe costs	2,95 M€
Operating revenu	10,12 M€
NPV	7,17 M€



**HEAT NETWORK**

# CONCLUSION AND NEXT STEPS (MAY BE)

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- the next step is to collect concrete prices for pipe network, connection costs, etc ...
- Economic analysis – return on investment
- Sitting together with different partners
- See if the network can be expanded



# WP 1.2: Geology & flow-modelling

<b>WP 1: Preparatory studies:</b>
<b>WP 1.2: Geology &amp; flow-modelling (VITO)</b>
<i>Task 1.2.1: thermal output of multi-radial well targeting Cretaceous chalks (VITO)</i>
<i>Task 1.2.2: assessment of costs for a geothermal / HT-storage system targeting Cretaceous chalks (VITO)</i>

# WP 1.2: GEOLOGY & FLOW- MODELLING

23/06/2020

## CRETACEOUS GEOTHERMAL POTENTIAL

- The **Cretaceous chalks** are a well-known **water bearing layer** in a large part of Flanders.
- In a first mapping of the geothermal potential in Belgium, Berckmans and Vandenberghe (1998) marked the chalks as a **viable geothermal resource**.
  - ✓ Potential:  $17,7 \times 10^8$  GJ of heat from the permeable upper part of the chalks.
  - ✓ Confirmation by the mapping of the geothermal potential of the Belgian provinces of Antwerp and Limburg in the context of INTERREG project GEOHEAT.App (2014).
- The Campine Basin is the most favorable region for geothermal applications or thermal energy storage.

## LESSONS LEARNED FROM PAST PRODUCTION FROM THE CHALKS

- The Cretaceous has been exploited for geothermal purposes at Herentals, Dessel and Turnhout.
  - ✓ In all cases, production was from the calcarenitic formations at the top of the Cretaceous (Houthem Formation and Maastricht Formation).
- The permeability of the underlying, fissured chalks proved to be too low to allow production rates that are needed for geothermal purposes.
- In case production from the fissured chalks could be augmented by connecting the different water bearing joints by radial jetting techniques:
  - ✓ it would significantly enlarge the area where projects could be developed.
  - ✓ it would make it technically feasible to use the chalks for deep, high temperature (HT) energy storage over a large part of Flanders.

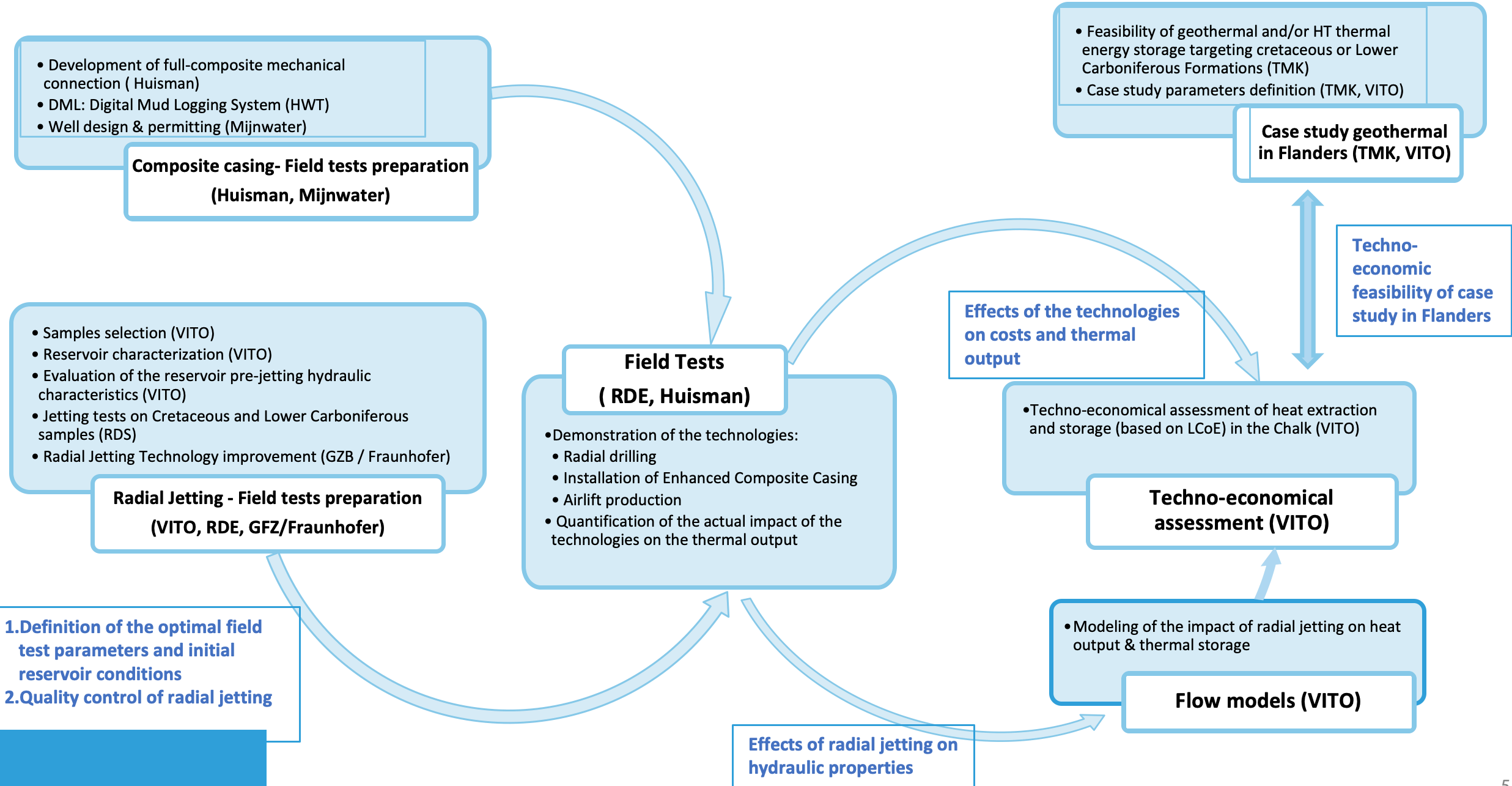
## LITHOSTRATIGRAPHIC DIVISION OF THE CRETACEOUS

Chronostratigraphy	Formation	Short lithological description	
Danian	Houthem	Pale beige soft fine to coarse grained calcarenite	
Maastrichtian	Maastricht	Pale soft coarse-grained calcarenite	
		Pale soft fine grained calcarenite with flint at the base	
		Pale beige fine grained flint bearing hard calcarenite	
	Gulpen	Pale grey very fine calcarenite with thick flint layers	
		White fine-grained chalk with abundant black flint layers	
		Predominately pale gray silty chalk with small flints (partly channel infill)	
		Campanian	Gray marl
			Gray marly chalk
			White fine-grained chalk
Vaals	Glaucanite bearing fine sand and silt (East) – marl (West)		
	Green clayey glauconite bearing sandy marl		
Santonian	Aken	Quarts sands with lignite	

“Maastrichtian” , single hydrogeological reservoir suitable for geothermal

Upper part of the underlying Gulpen Formation reservoir to some extent, with an overall lower permeability.

No suitable geothermal reservoir in the Campine Basin



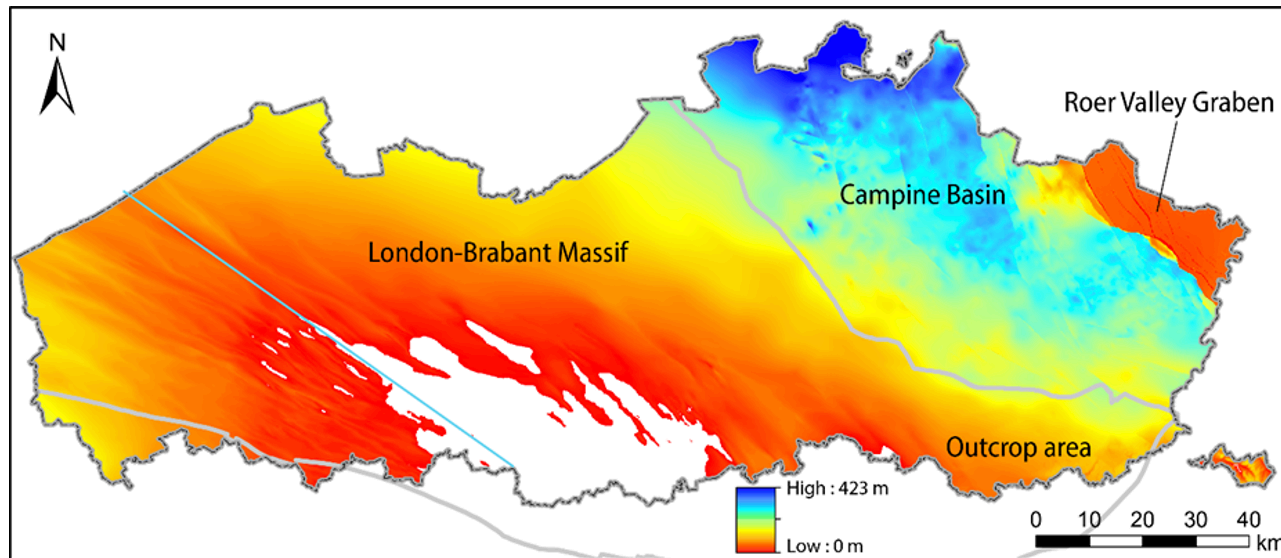


## EVALUATION OF THE RESERVOIR CHARACTERISTICS OF THE UPPER CRETACEOUS AQUIFER IN FLANDERS

- All available relevant data collected.
  - ✓ Porosity and permeability values available from geophysical well logs and direct measurements on core samples and pump tests.
- Maastrichtian aquifer in the Campine Basin (Maastricht-Houthem formations) :
  - ✓ porosities from 30 % to 45 %
  - ✓ permeabilities in the range of 50 mD to 1200 mD } Favorable geothermal reservoir that might be improved by radial-jetting
- Chalks below Maastricht aquifer (Gulpen, Nevele and Vaals Formation)
  - ✓ primary porosity is about 20-30%
  - ✓ permeability dramatically drops to 10 mD or below detection limit
  - ✓ water-bearing fissures become more important than matrix porosity. } Less favorable but radial-jetting could improve the reservoir hydraulic properties

## THICKNESS OF THE RESERVOIR IN FLANDERS

- Thickness of the reservoir derived from the recent 3D geological model of Flanders.

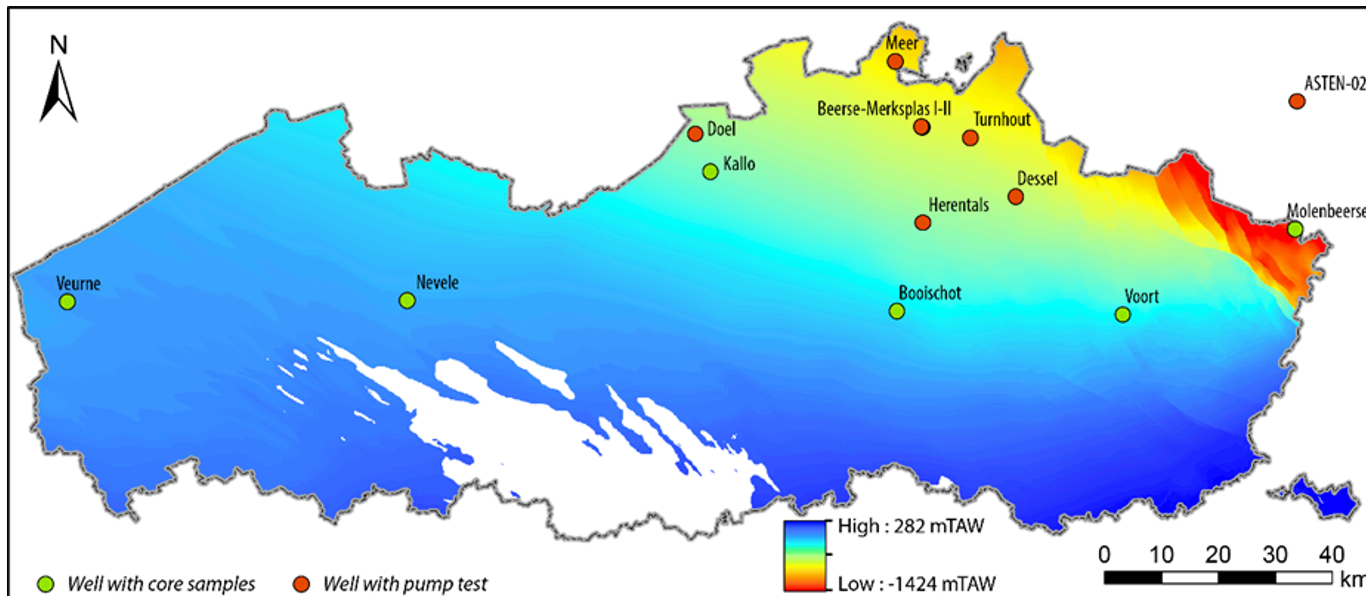


Thickness map of the Cretaceous in Flanders with indication of the main geological regions. (based on the 3D geological model of Flanders, Deckers et al., 2019)

- ✓ In the northern part of Antwerp, the Cretaceous reaches its maximal thickness and depth of respectively about 400 m and -950 m.
- ✓ In the rest of Flanders Cretaceous is above -500 m. Except in the Roer Valley Graben, but there the 60 m calcarenites at -1200 m are completely cemented, and unfavorable for geothermal use.

## CHARACTERIZATION OF THE CRETACEOUS IN DE SUBSURFACE OF FLANDERS

- Cores were selected sampling different lithologies at different depths and locations.
- Petrographical characterization and X-ray tomography were conducted on the core samples.



Subcrop map of the top Cretaceous in Flanders, with indication of the sampled and tested boreholes.

- ➔ **6 boreholes selected**, equally spread over the subcrop area of the Cretaceous in Flanders, covering the different structural areas: Roer Valley Graben, Campine Basin and London-Brabant Massif.
- ➔ **4 formations sampled and analyzed:** Houthem, Maastricht, Vaals Nevele Formation (western equivalent of Gulpen and Vaals Formation).

## JETTABILITY OF THE LOWER CARBONIFEROUS LITHOLOGIES

- Lab experiments performed to define the jettability of selected samples
- The jettability of the Lower Carboniferous carbonate has been tested by RDS in the past. However, because the orientation of the samples was not specified and that the jettability was not homogeneous in all directions it has been decided to perform additional jetting tests.
- New Lower Carboniferous carbonate samples have been selected in the Moha quarry beginning of June.
  - Analog to the Dinantian reservoir targeted in the Balmatt site
  - Tests will be performed in the coming weeks

## JETTABILITY OF THE DIFFERENT CRETACEOUS & LOWER CARBONIFEROUS LITHOLOGIES

- Lab experiments performed to define the jettability of selected samples
- **Cretaceous samples**
  - Samples representative of Cretaceous formations have been selected
  - Results of jetting tests performed by RDS:
    - Both outcrop samples were easily jetted with plain water → no acid needed
    - Nearly identical jetting parameters.
    - Only took 4 minutes to penetrate both samples, formations is easily jettable downhole and good results are expected.



Calcarenites from Sibbe underground quarry: equivalent for Maastricht and Houthem Formation.



Chalk from Loën quarry: equivalent for Gulpen formation.

## FLOW MODELLING OF IMPACT OF RADIAL JETTING

- Single well concept
  - ✓ Numerical models of the effect of radial jetting on the heat output from wells targeting the cretaceous have been performed using COMSOL Multiphysics.
  - ✓ The case study of a single well targeting a reservoir with properties similar to the cretaceous geothermal reservoir in Herentals has been modeled.
  - ✓ Paper accepted for publication: Efficiency of single-well geothermal systems with multi-lateral drills. Authors: S.Erol, V. Harcouët-Menou, B. Laenen, P Bayer. Geothermics 89 (2021) 101928
- Classical doublet systems
  - ✓ In the coming weeks the effect of radial jetting on classical geothermal doublet systems targeting the cretaceous will be modelled.
  - ✓ The same software will be used



## NEXT STEPS AND EXPECTED RESULTS

- VITO will use the flow models to assess the impact of radial drilling on the thermal output of wells targeting the Chalk aquifer in Flanders.
  - VITO will update the geothermal resource assessment for the chinks and for the Carboniferous Limestone Group in Flanders. The updated resource assessment will be made available to the public through the Databank Ondergrond Vlaanderen (<https://dov.vlaanderen.be/>).
- The test for the radial-jetting technology originally foreseen in the Cretaceous have been shifted to the Lower Carboniferous limestone. RDS and VITO are preparing for field tests in well MOL-GT-03 (Mol).
- In a final step, VITO will perform a techno-economical assessment of heat extraction and storage (based on LCoE) in the Chalk taking accounting for the effects of radial drilling, the installation of Enhanced Composite Casing and airlift production.

# WP 1.3: DML: Digital Mud Logging System

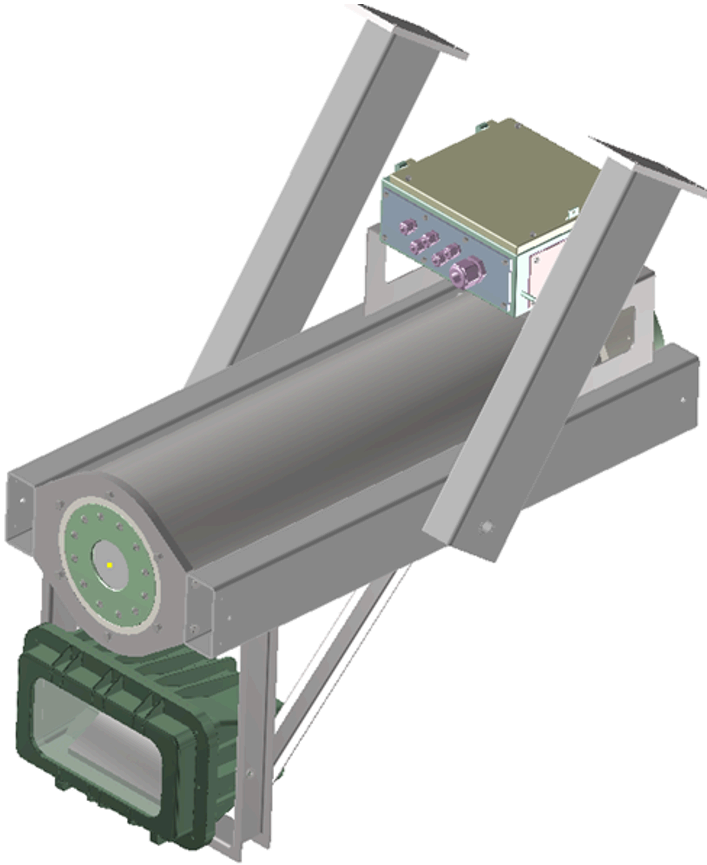
<b>WP 1: Preparatory studies:</b>
<b>WP 1.3: DML: Digital Mud Logging System (HWT)</b>
<i>Task 1.3.1: final design digital mud logger</i>
<i>Task 1.3.2: manufacture test set-up of digital mud logger</i>
<i>Task 1.3.3: software development data processing (cuttings: carbonate, clay, sand, other...)</i>

### **Task 1.3.1: Design digital mud logger; selection and modification of components for operation in an environment with explosive atmosphere (ATEX).**

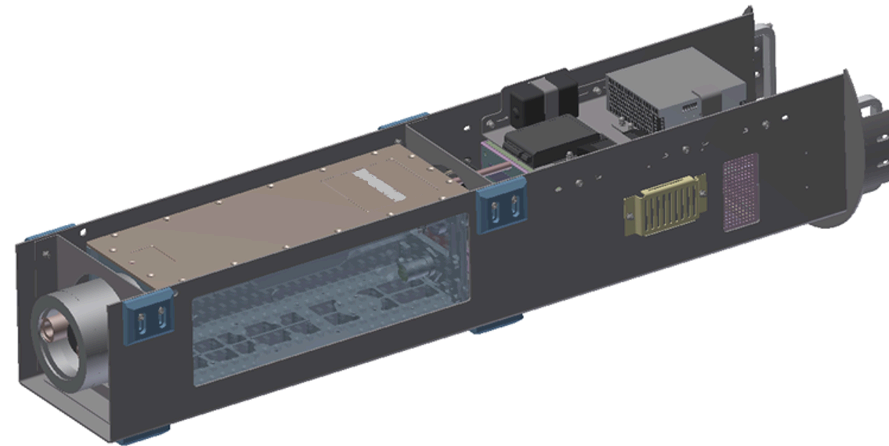
A drilling rig is divided into different zones, in which the likelihood of the presence of explosive atmospheres dictates the classifications of a zone. Since mud can potentially contain gasses, all the equipment that operates near (untreated) mud should be explosion safe. The equipment envisioned to provide a solution for Digital Mud Logging (sensors, illumination, data acquisition box and computer) is not ATEX certified on default. Furthermore, suppliers of (sub) components are not always familiar with the directives and/or authorized to deliver ATEX certified components. To prepare the DML system for operation in an ATEX zone, a development process is setup, consisting of the following topics:

- 1. Design of an Ex d (Flameproof) enclosure for the sensor. The enclosure itself has negative effects on the measurement performance, such as heat build-up and material transparency, which are taken into account by integrating a cooling apparatus and special purpose low absorption materials in the design.*
- 2. Setting up requirements and purchasing of a suitable illumination source.*
- 3. Preparing auxiliary equipment (data acquisition box and computer) to work with the sensor in the ATEX environment.*

WP 1.3.1 Design digital mud logger; selection and modification of components for operation in an environment with explosive atmosphere (ATEX)



- Design sensor and auxiliary equipment carriage
- Design of an Ex d (Flameproof) enclosure for the sensor
- Setting up requirements of a suitable illumination source
- Investigate auxiliary equipment (data acquisition box and computer)



### Task 1.3.2: Manufacture test set-up of digital mud logger

In finding a suitable location to uninterruptedly measure the mud flow, the resolution of the measurement device, the particles to be detected and environmental distortions were governing. Correct illumination and mitigation of unwanted scatter is of utmost importance for the generation of usable datasets. A test setup was built to identify relevant geometrical and environmental parameters, to investigate different positioning ideas, and to setup a guideline for workable setups. Approximately 150 test measurements were taken.

Light source must be ATEX proof to work inline in hazardous areas (where mud is present).

Light source for sensor must be bundled to increase intensity at measuring surface. Special mirror shape was designed.

### WP 1.3.2 Manufacture test set-up of digital mud logger



Figure 2: DML test setup for measurement on shale shaker

ATEX light source  
modification

original reflector

luxmeter value: 1100



Custom build reflector

luxmeter value: 3800





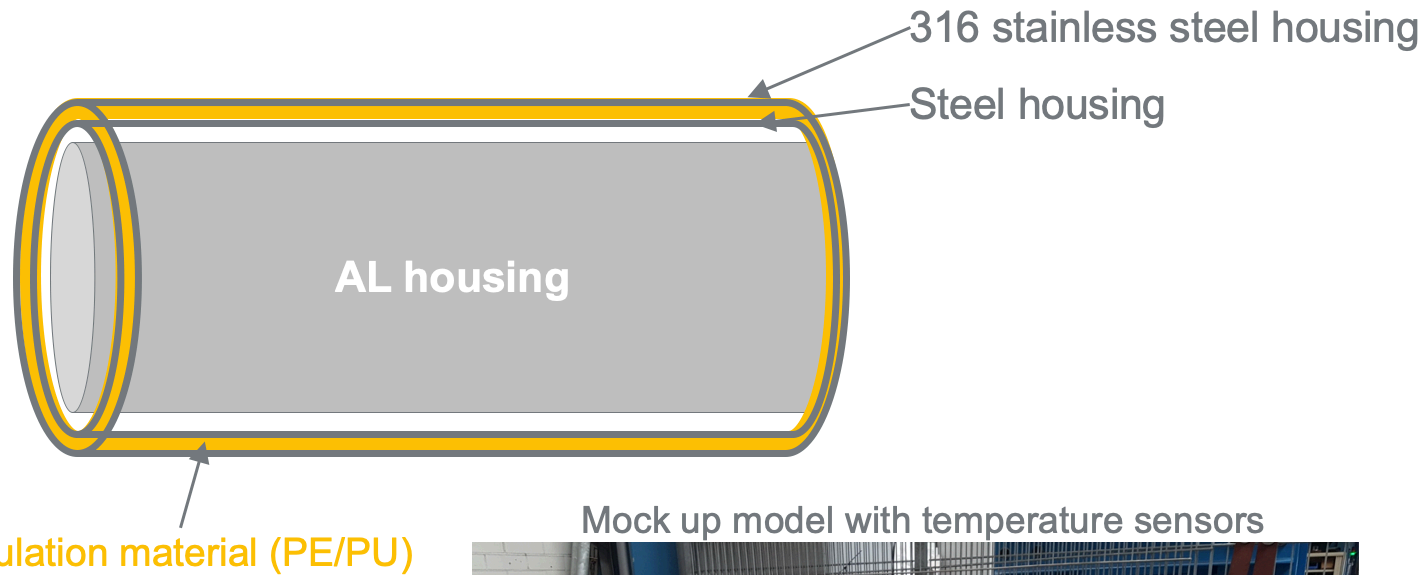
### Task 1.3.2: Manufacture test set-up of digital mud logger

- Sensor (inside enclosure) generates heat
- At high temperature the sensor fails (stops), thus temperature must be controlled.
- Cooling is done by means of a vortex cooler
- Test setup (with heating elements) made to simulate sensor and auxiliary equipment
- This setup is tested at room temperature and...

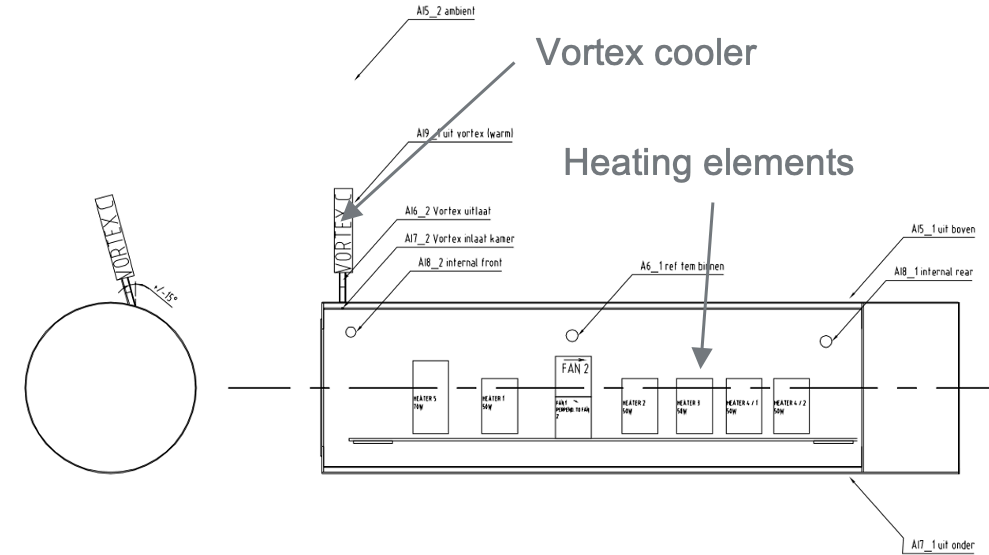
# CAGE

## WP 1.3 DIGITAL MUD LOGGING SYSTEM

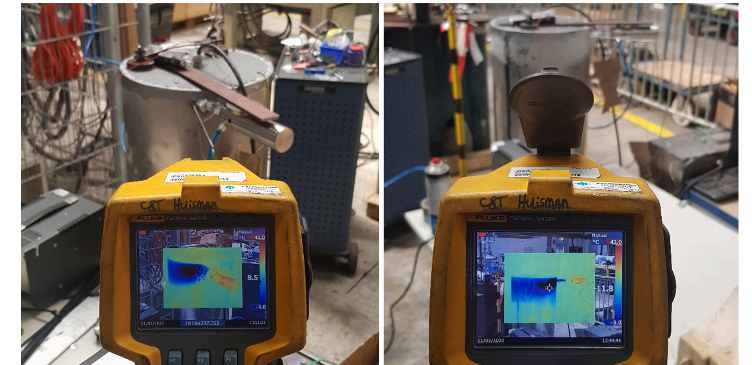
### WP 1.3.2 Manufacture test set-up of digital mud logger



Mock up model with temperature sensors



Temperature distribution



### Task 1.3.2: Manufacture test set-up of digital mud logger

The setup is tested inside an oven up to 60deg to simulate elevated environmental temperature.

### WP 1.3.2 Manufacture test set-up of digital mud logger

Mock up in oven (elevated temperature simulation)

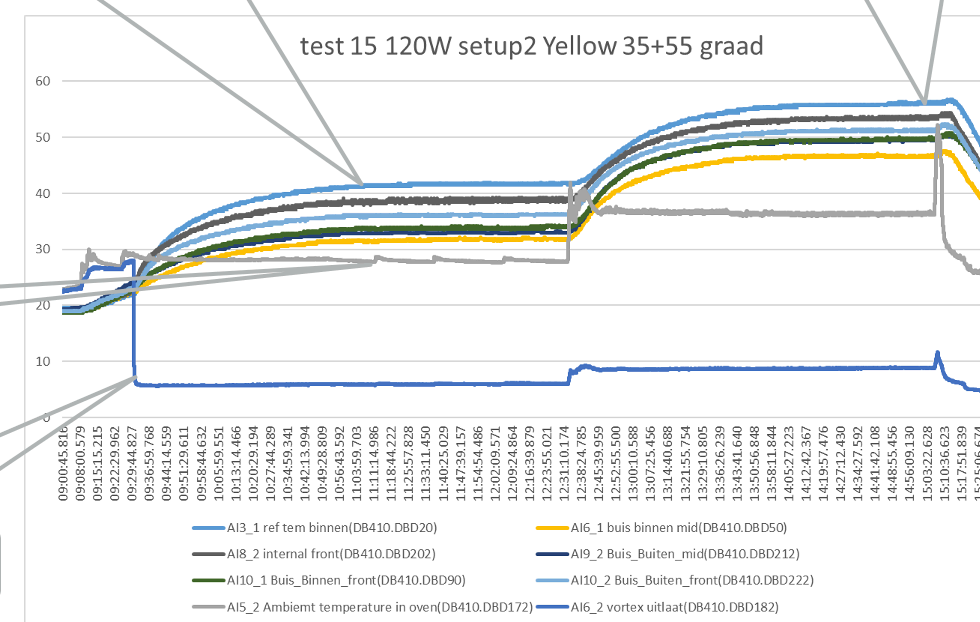


- Max. temperature inside the inner pipe  
~42°C @35°C environment temperature

- Max. temperature inside the inner pipe  
~57°C @55°C environment temperature

Environment (oven) temperature

Vortex cooler-cooling temperature



### Task 1.3.3: Software development data processing

Digital analysis of drilling mud will assist in assessing borehole stability and improve operational practice with regards to drilling fluid parameters. Widespread use will facilitate systematic documentation and information from wells and facilitate comparison of stratigraphic data between wells.

Approximately 300 measurements, with various mixtures of mud and particles, were conducted to verify and improve the material recognition performance of the software.

Recognition of typical reflectance “signature”

### WP 1.3.3 Software development data processing



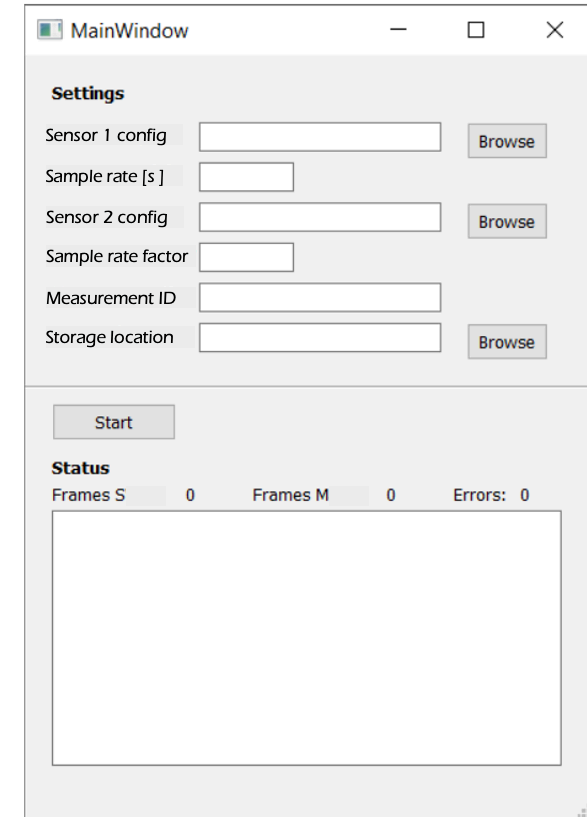
Figure 6: Reference trays of dry samples and mud mixtures

Specimens to validate software  
recognizes various types of materials

#### Design, build, test:

- Functionality for user
- Hard & Software selection
- Interface design
- Remote controlling of sensor
- Data management (size, structure, parameters, consolidation)
- Visualization

#### Example





Worldwide Lifting, Drilling and Subsea Solutions

# WP 1.4: Acoustic Multi Sensoric Process Analysis

## WP 1: Preparatory studies:

### WP 1.4: Laboratory Acoustic Multi Sensoric Process Analysis testing (GZB / Fraunhofer)

*Task 1.4.1: analyse and fine-tune the I/O data and determine a usable bandwidth of parameters*

*Task 1.4.2: determine the type of sensors being required in order to record pertinent data*

*Task 1.4.3: monitor the drill string / jet / coil response and analyse its output / response signals*

*Task 1.4.4: perform test program with autoclave system iBOGS with MOUSE*

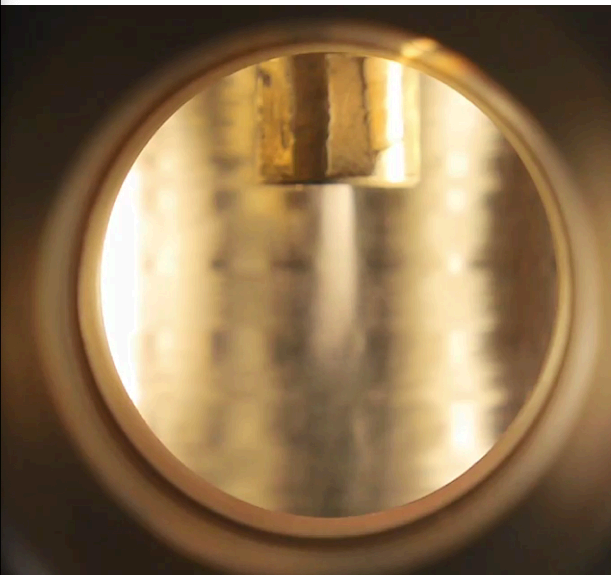
*Task 1.4.5: development of an appropriate MWjet online monitoring tool*



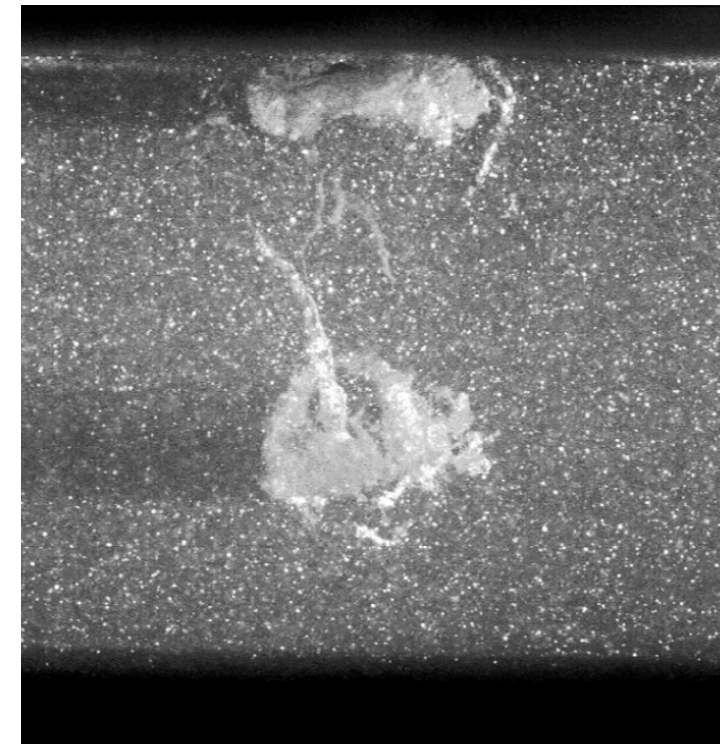
# CAGE Midterm Review Meeting June 2020

## Acoustic Multi Sensoric Process Analysis (MOUSE)

**Shahin Jamali**  
**Volker Wittig**



High pressure water Jet  
Increasing Cavitation

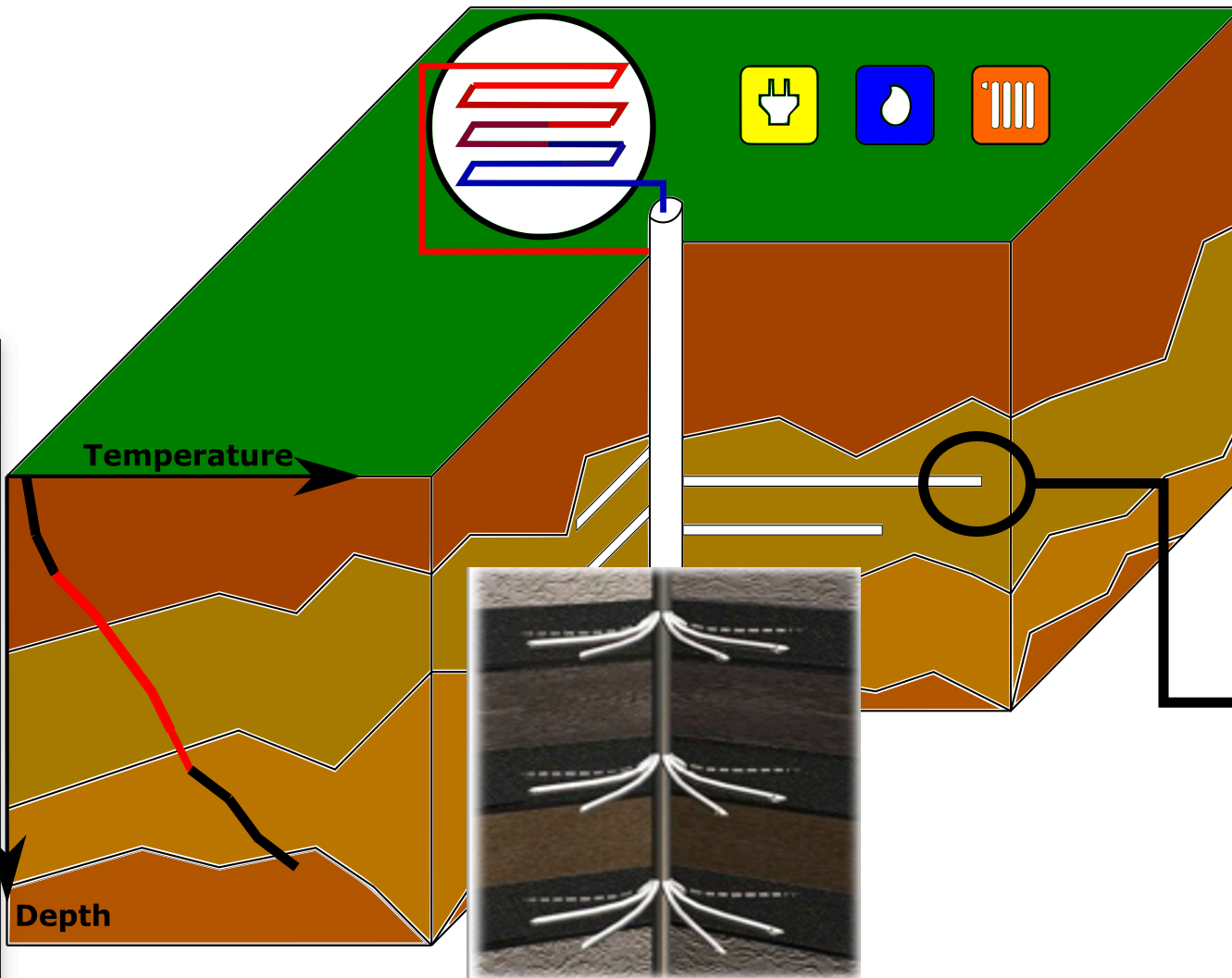


# GZB / Fraunhofer IEG - WP 1.4 details

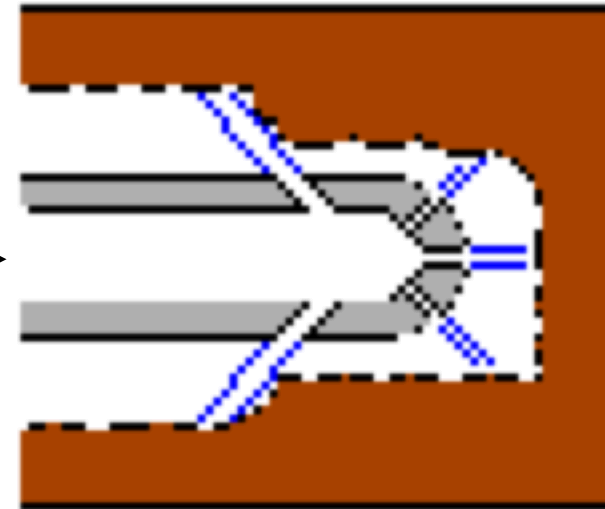
- **WP1:** Analyze and fine tune I/O data incl. a usable bandwidth of parameters
- **WP2:** design sensors being for recording pertinent data
- **WP3:** Monitor drill string / jet / coil response + analyze response signals
- **WP4:** Perform MOUSE tests under reservoir type conditions in autoclave system iBOGs
- **WP5:** Development of an MWJet online monitoring tool → MOUSE system
- **WP6:** Field test of this system during jetting operations in NL

WP 1.4: Laboratory Acoustic Multi Sensoric Process Analysis testing (GZB / Fraunhofer)			
Task 1.4.1: analyse and fine-tune the I/O data and determine a usable bandwidth of parameters			X
Task 1.4.2: determine the type of sensors being required in order to record pertinent data			X
Task 1.4.3: monitor the drill string / jet / coil response and analyse its output / response signals			X
Task 1.4.4: perform test program with autoclave system iBOGS with MOUSE			X
Task 1.4.5: development of an appropriate MWjet online monitoring tool			X

# Radial Jet drilling

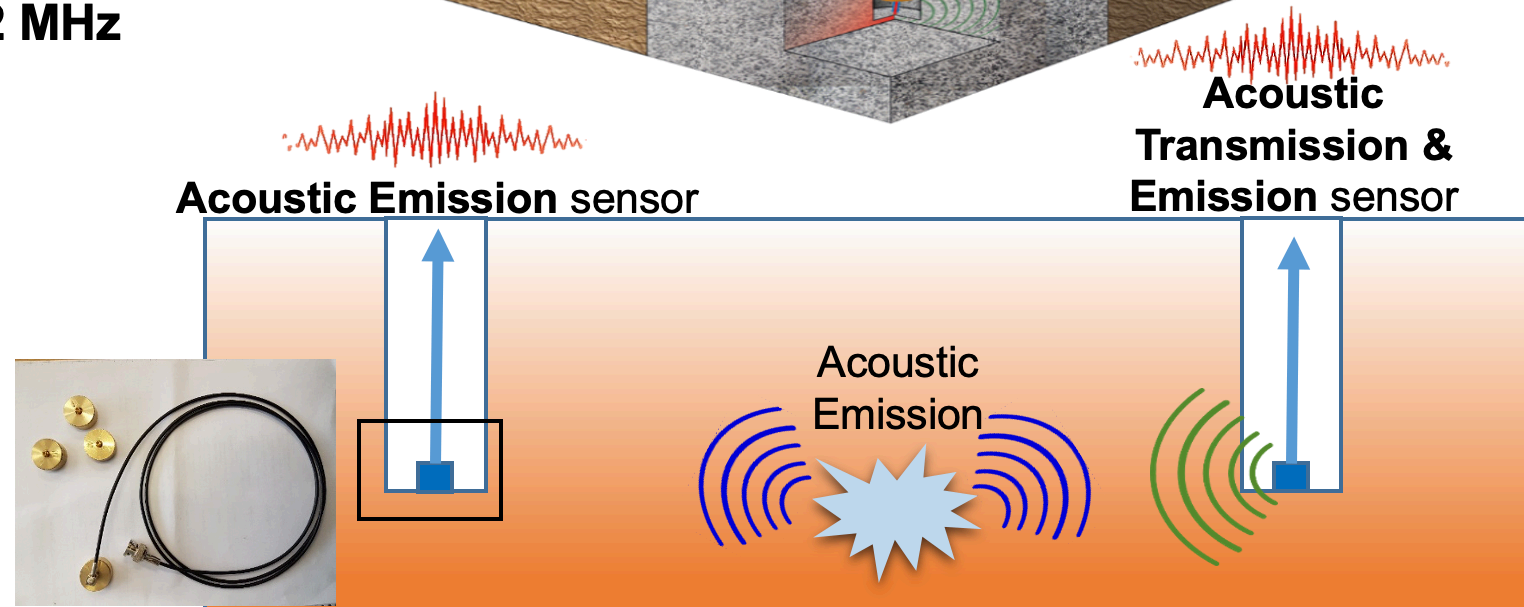
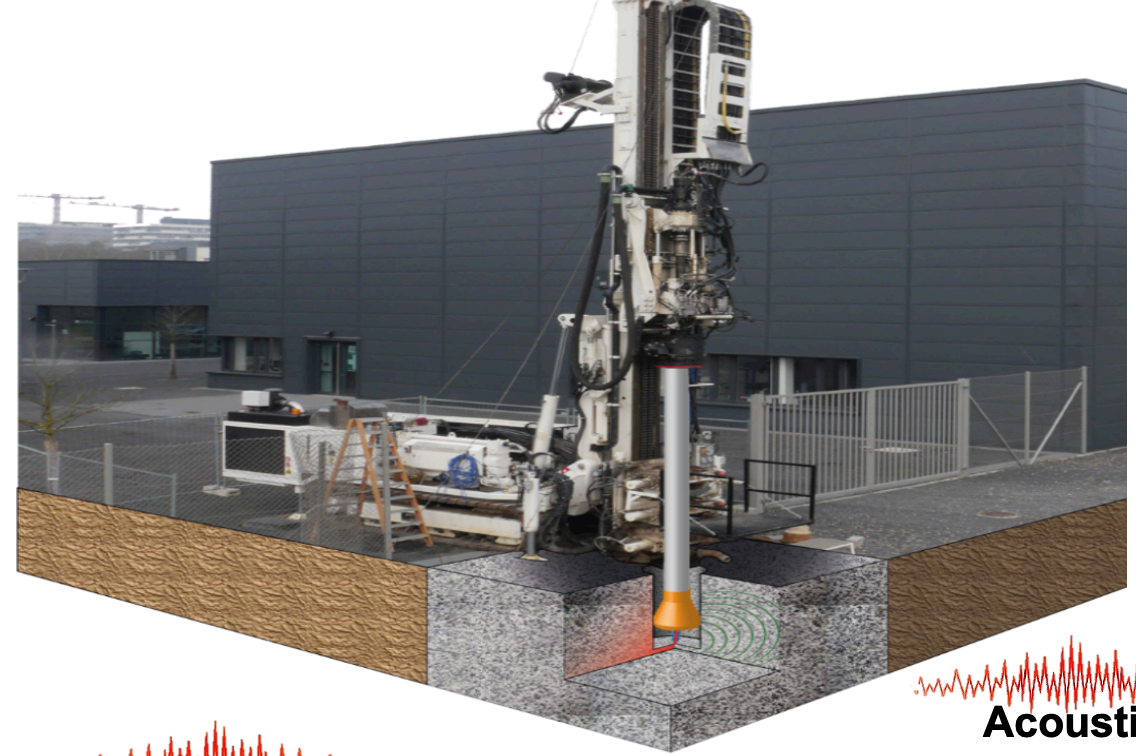


- **Heat exchanger** → electricity, warm water, heating
- **Main well** → multi laterals into formation layers
- **Jetting nozzle** → forward and backward oriented nozzles

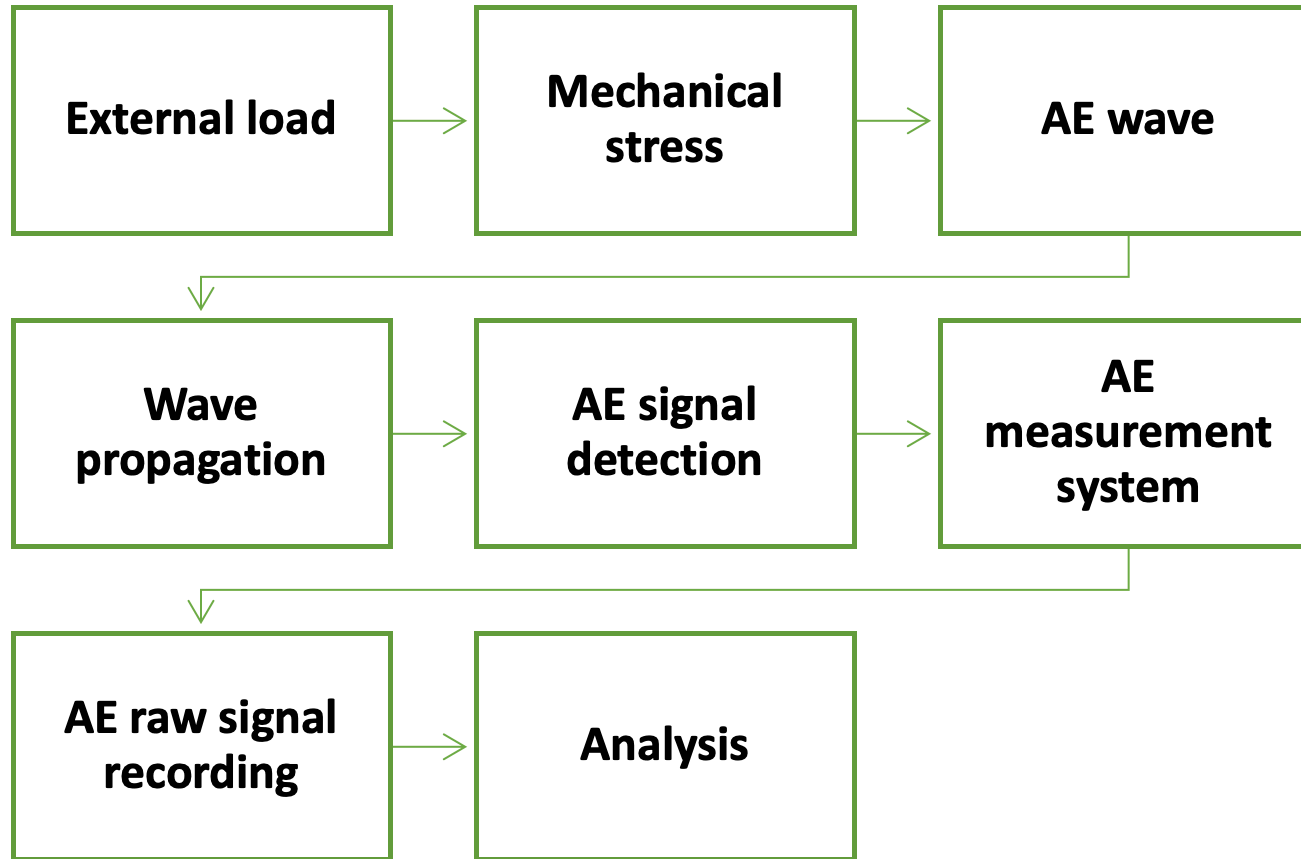


# MOUSE System

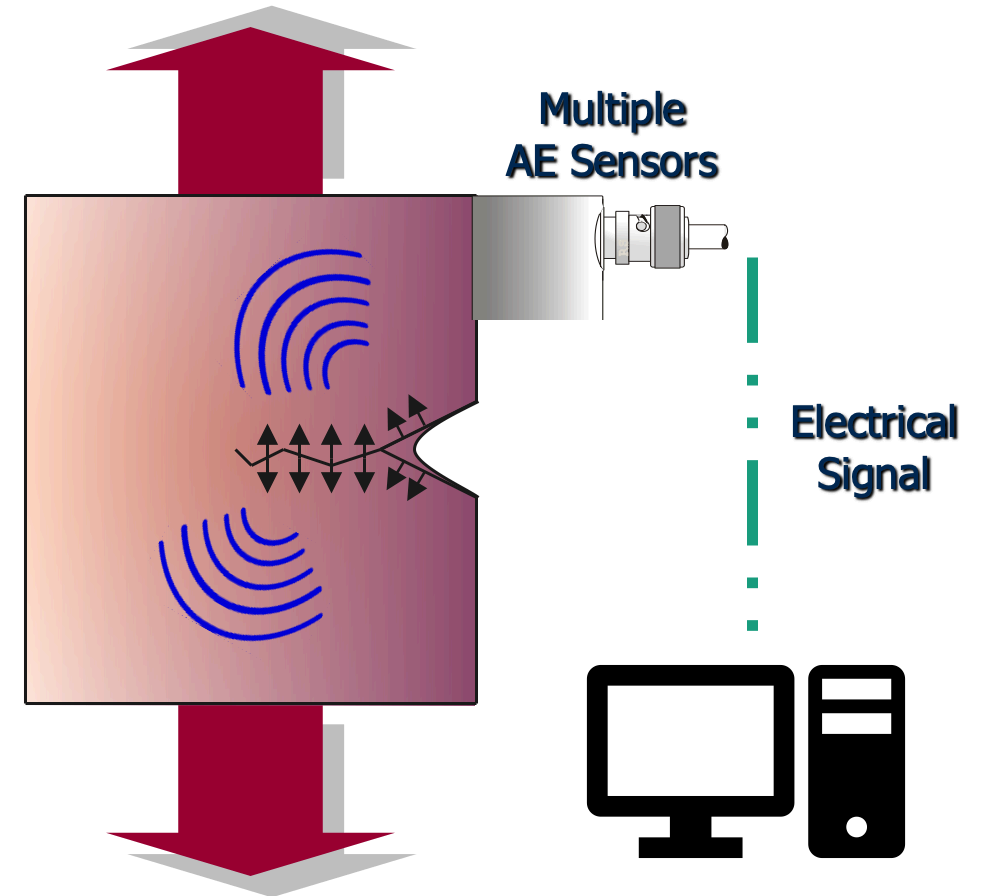
- **Designed-for-purpose Self-made AE sensors**
- **amplification** → low-noise preamplifier
- **18-channel** measurement arrangement
- Frequency response range: **1 Hz to about 2 MHz**
- Sampling rate: **20 MHz**, 14-bit resolution
- **Transmission signal** → freq. range: **1 - 2 MHz**
- **Signal characterization**
- **Signal feature extraction**
- **Machine learning based performance prediction and optimization**



# MOUSE System



Thermo-, Chemo-, or Hydro-mechanical loads





# Autoclave reservoir type simulators



→ Pressure and flow meter sensors (input)

→ High pressure line

→ Back-pressure control valve

→ Pulsation generator

→ Pressure cell

→ Data acquisition system

→ Water-reserves

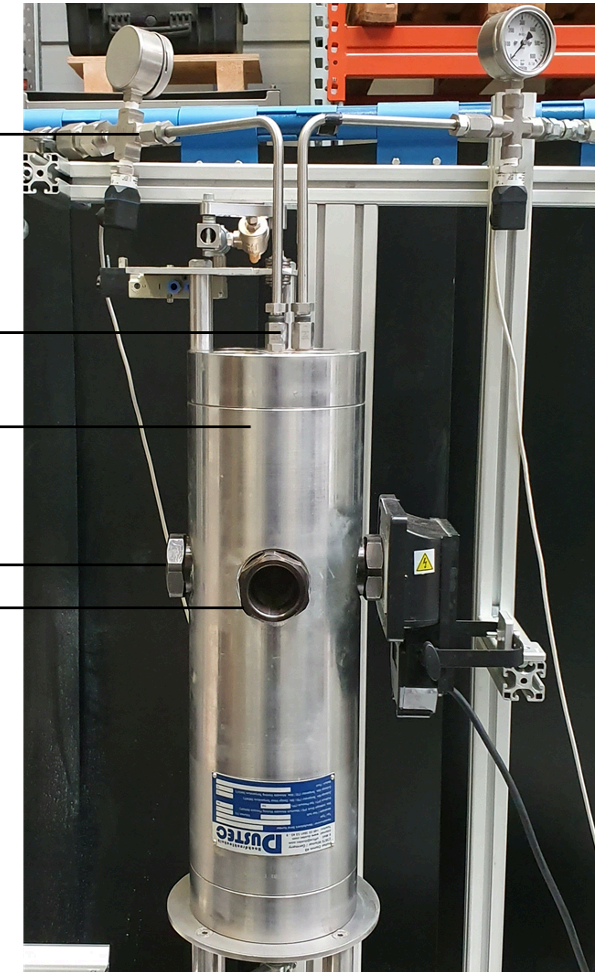
→ Secondary pump

← Pressure sensors

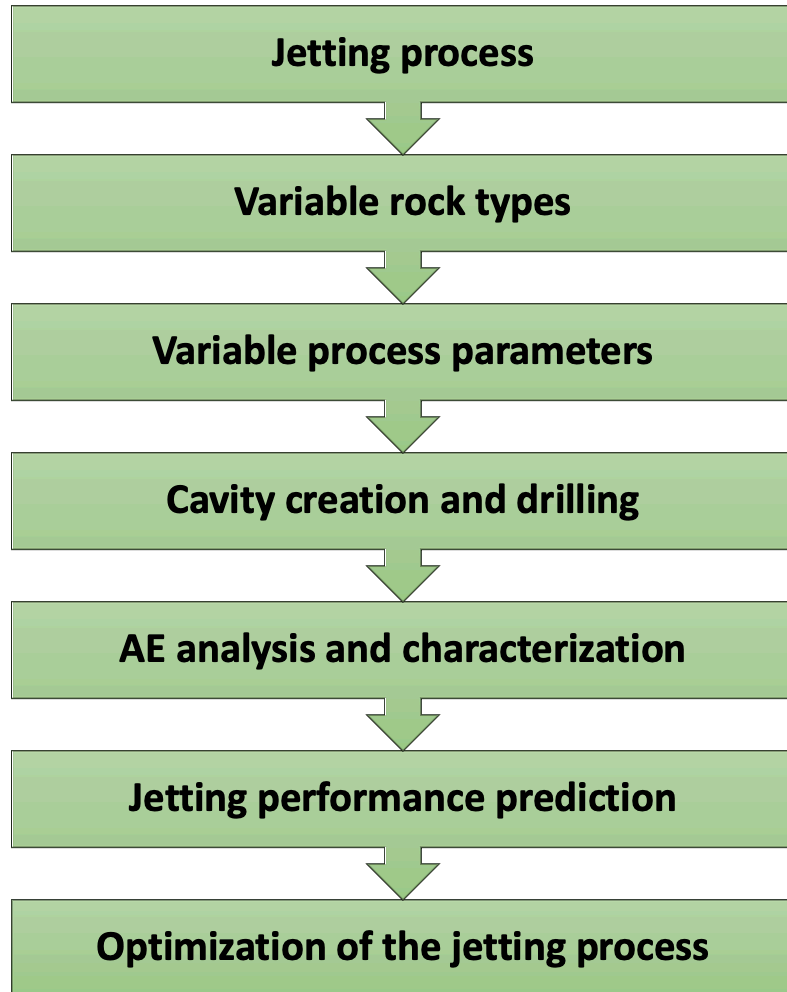
← Nozzle and fluid inlets

← Pressure vessel

← Sapphire windows



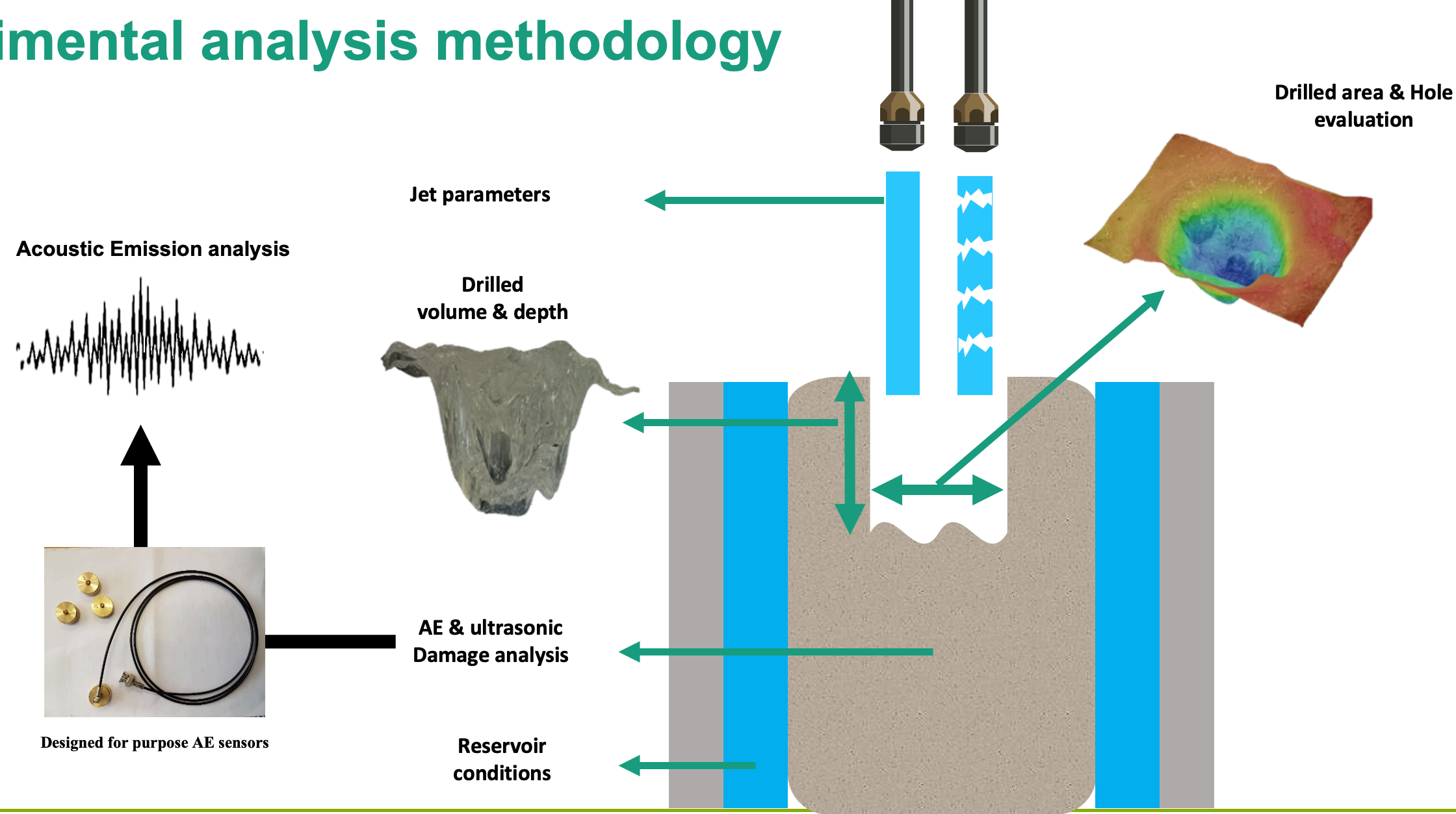
# Jetting at reservoir type conditions



- Over 400 experiments
- Reservoir simulated conditions
- Four rock types
- Jetting duration →
  - Short pulses (>25 ms)
  - long duration (seconds scale)
- Jetting modes →
  - Continuous jet
  - Pulsating jet
- Pressure & flowrate →
  - Nozzle & downhole pressures (25, 35, and 65 bars)

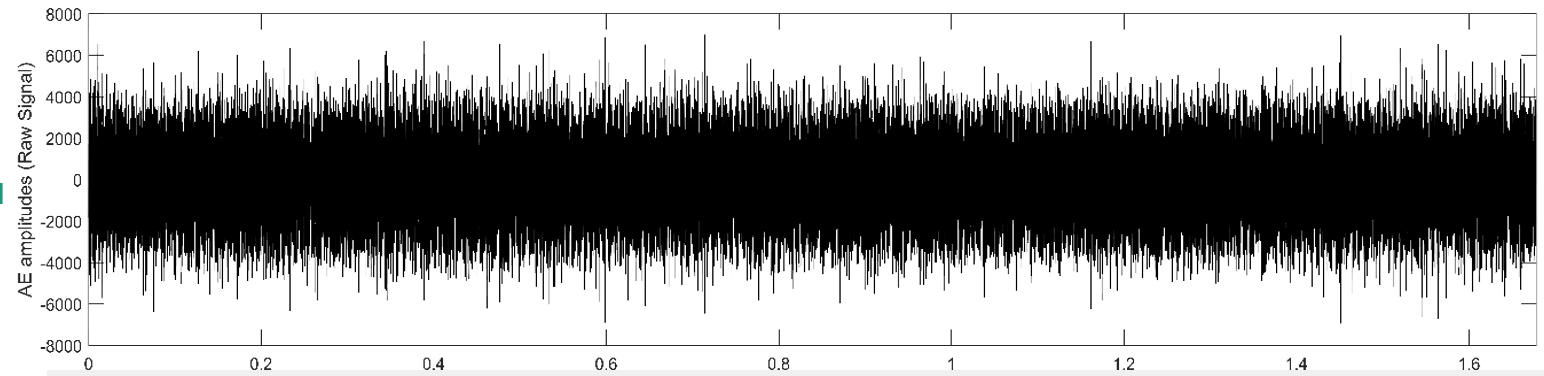


# Experimental analysis methodology

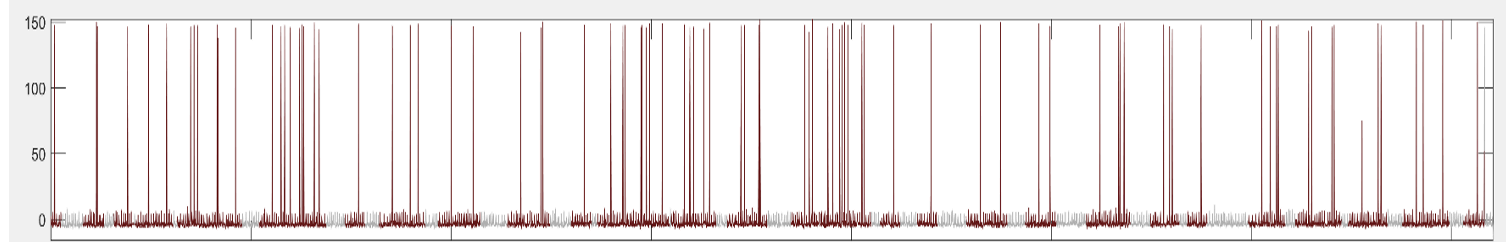




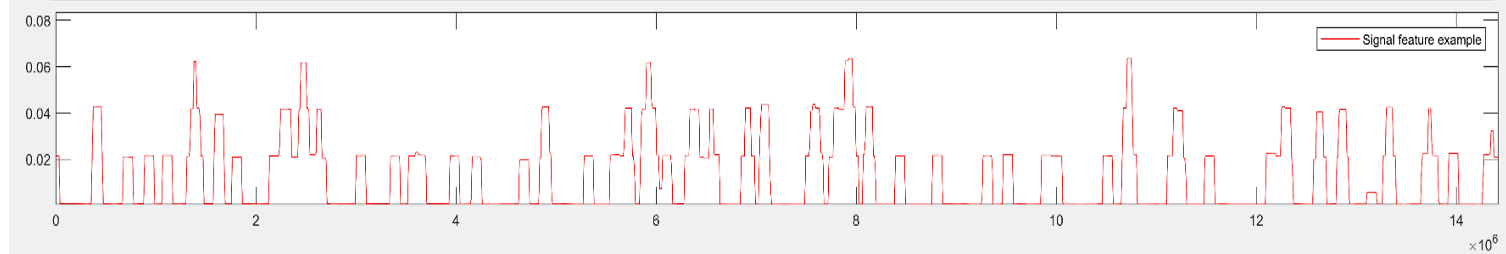
**High pressure Jetting  
Signal (20 Mil.  
Datapoints per sec.)**



**Detection of relevant  
events**



**Characterization  
&  
the trending index**

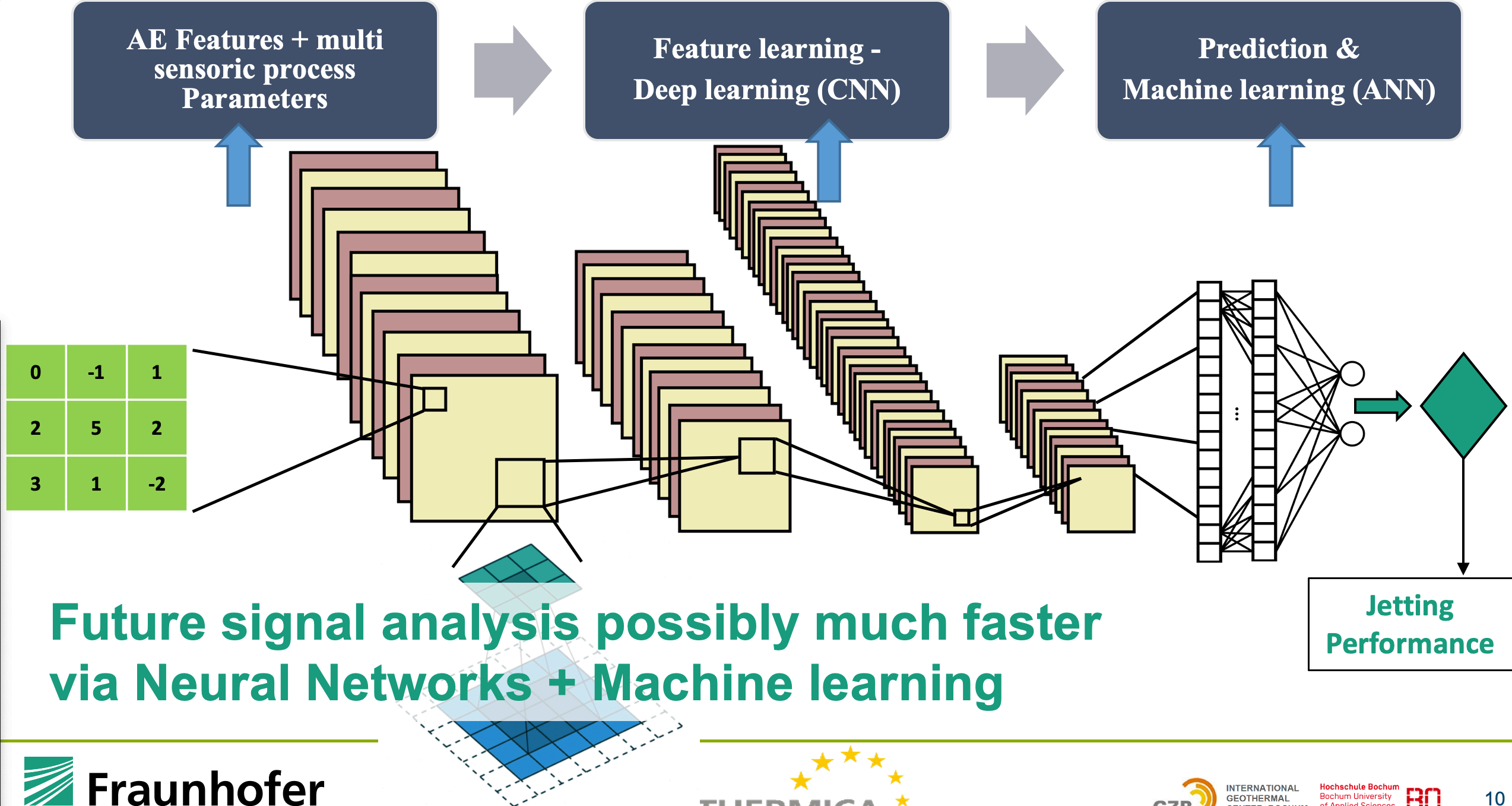


**Event categories**



**Classification of the  
AE signal**

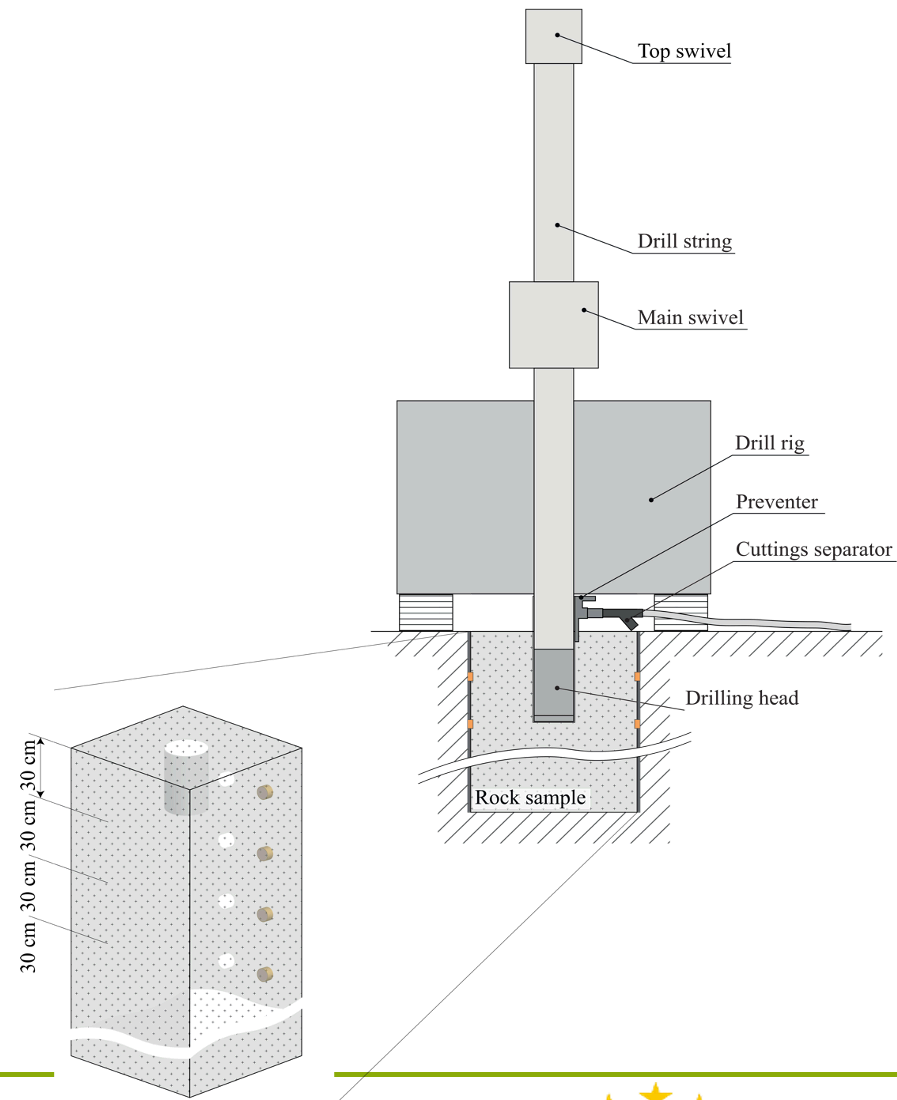




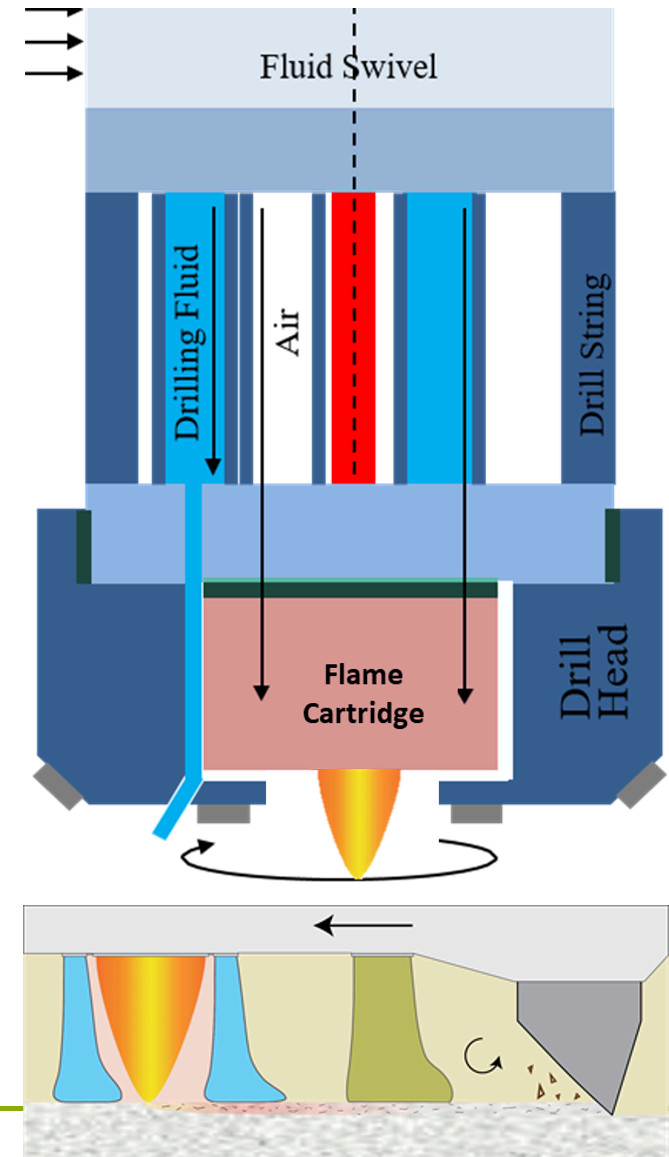
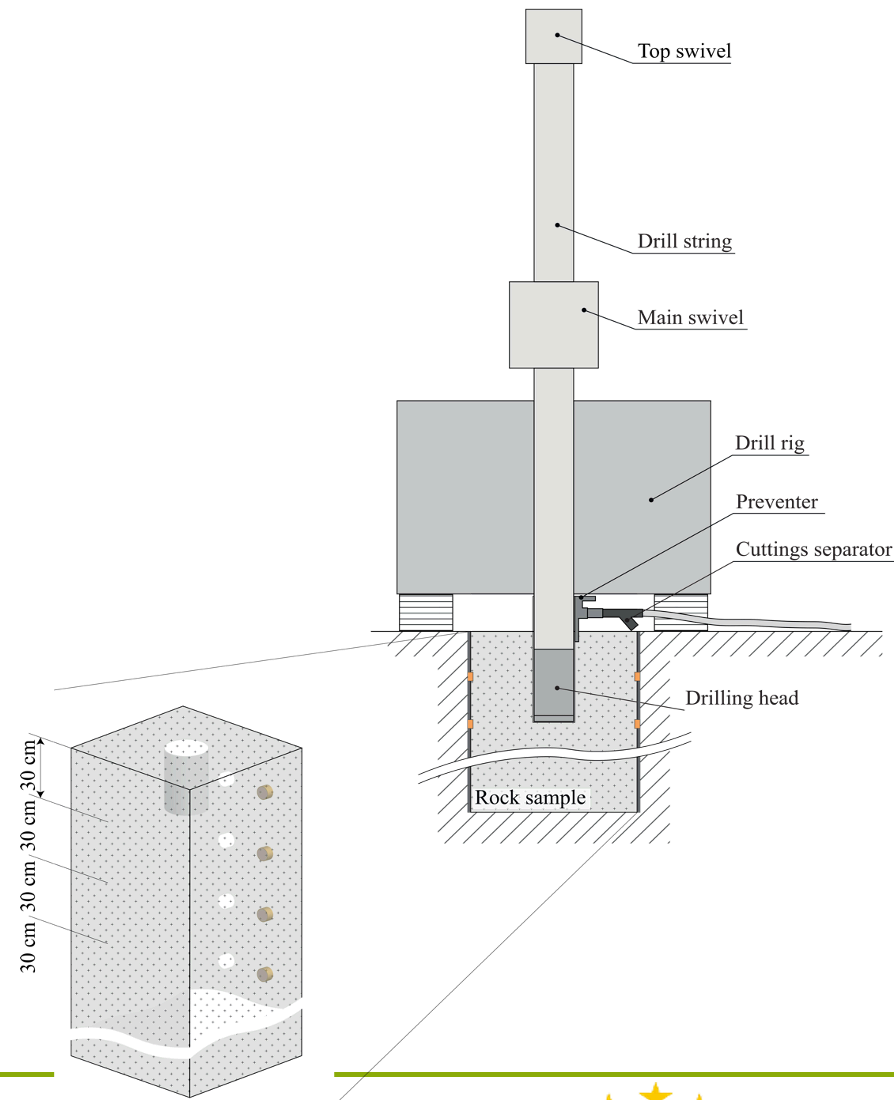
# Field test - Preparations & planning & activities

- **Field jetting tests and process monitoring in a well at NL site (Oct 2020)**
- **AE sensor design enhancements** → adaptability to field application, depth, and temperature of the well
- **AE sensor placement and data transfer** Plan development and solution possibilities
- **Reservoir simulated Jetting experiments** → Further characterization of jetting AE signals
- **Analysis methodology development for fast and real time data display**

# Monitoring of any no-contact drilling processes

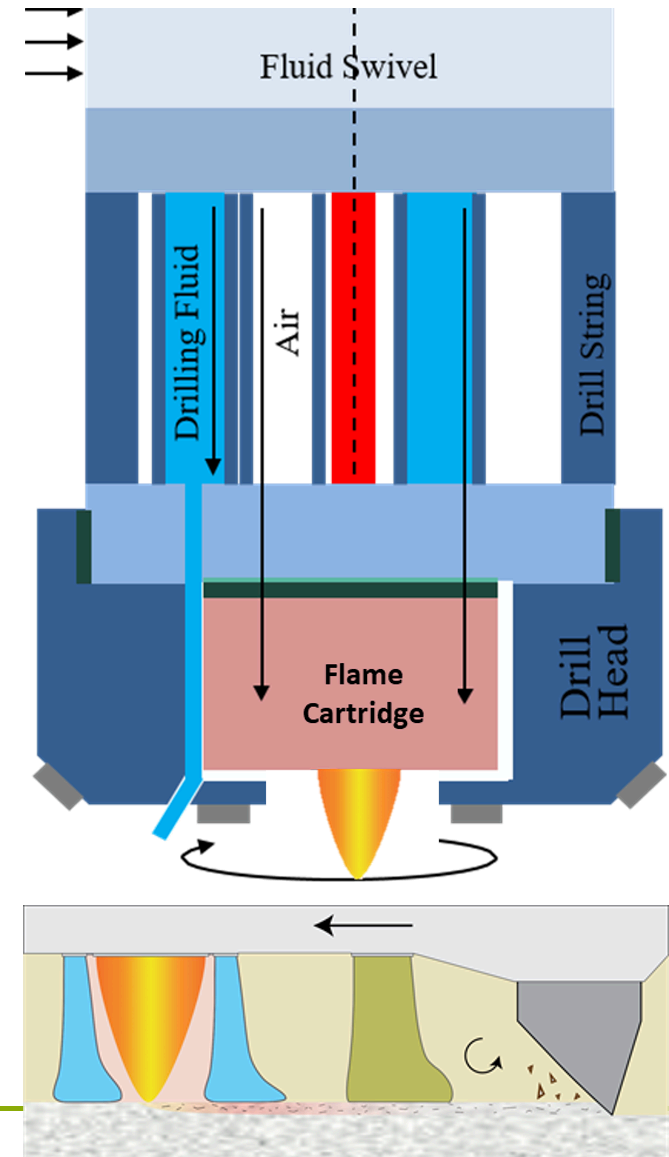
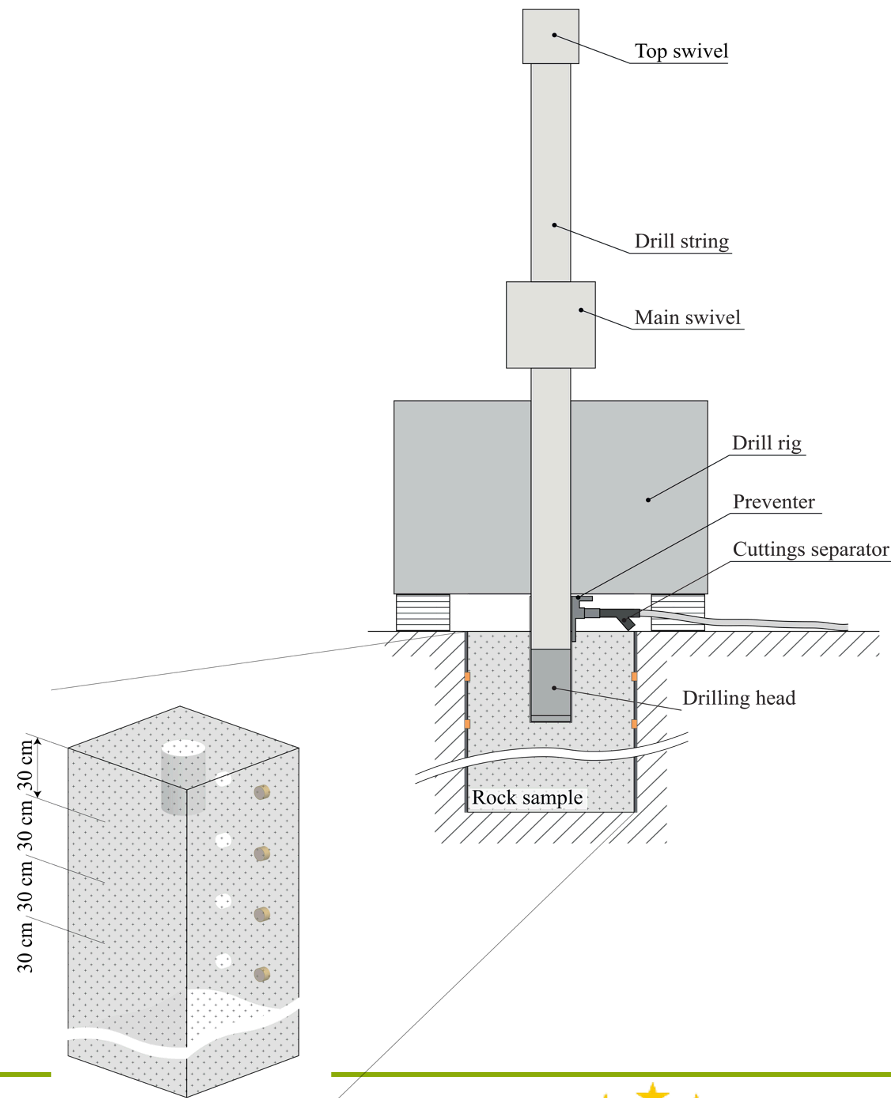
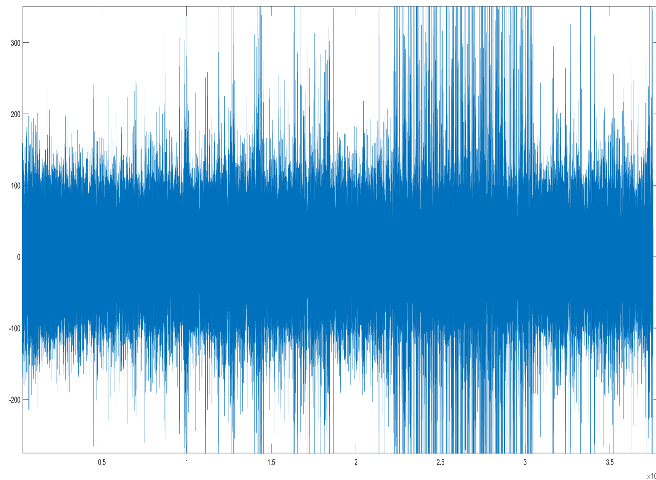


# Monitoring of any no-contact drilling processes

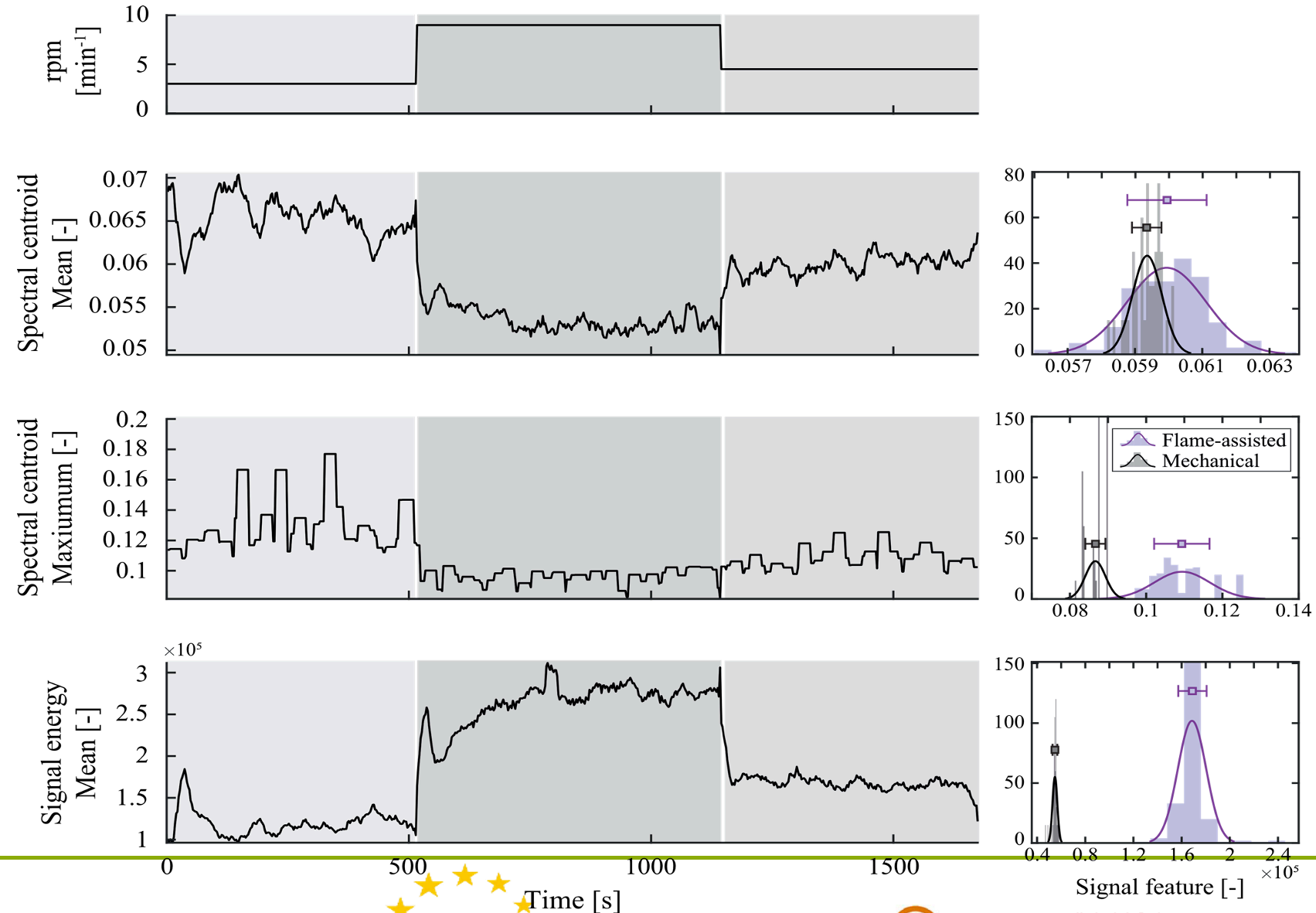


# Monitoring of any no-contact drilling processes

## Combined thermo(Flame jet)-mechanical drilling

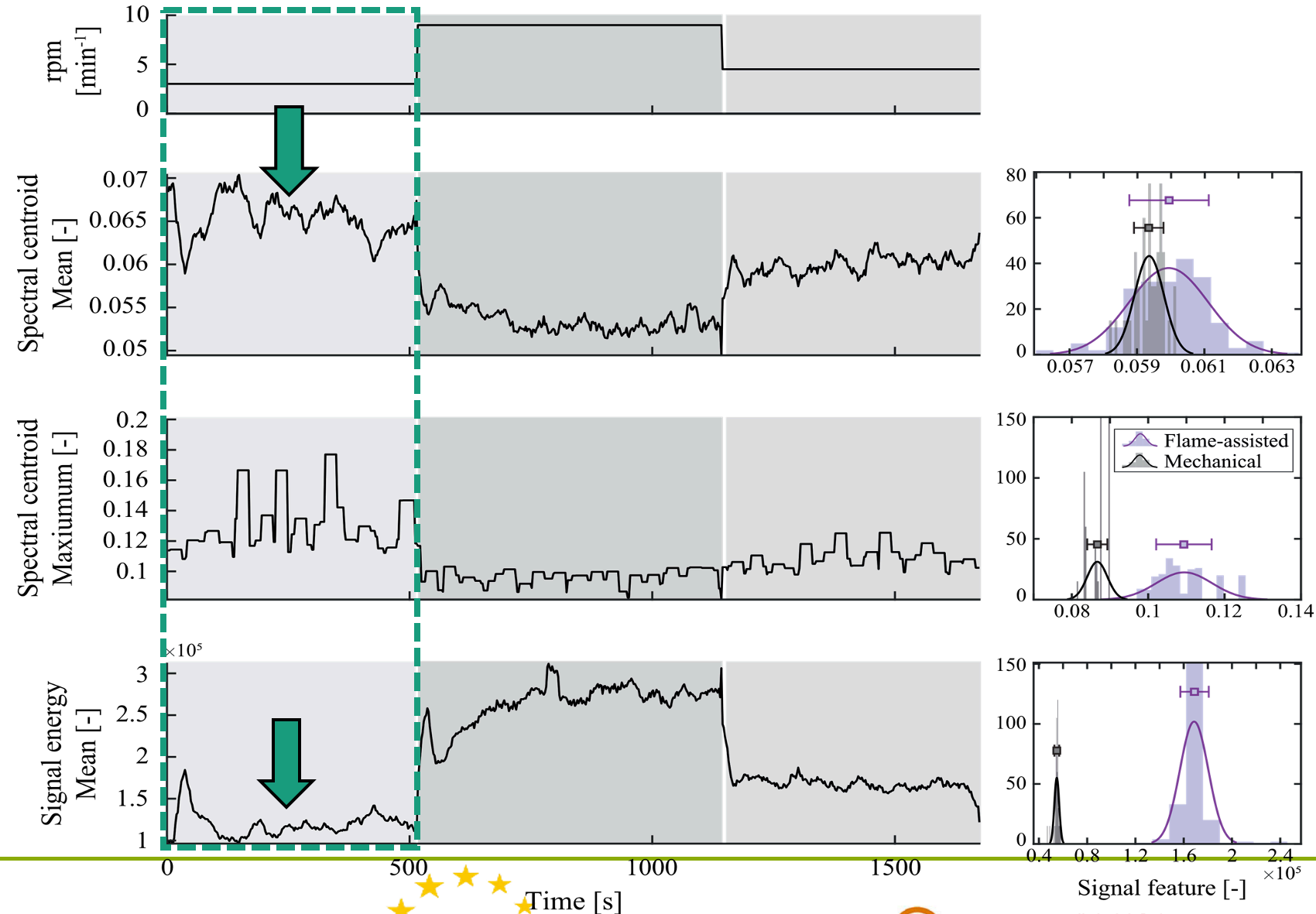
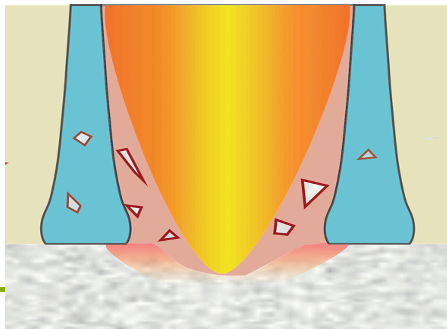


# Monitoring of any no-contact drilling processes



# Monitoring of any no-contact drilling processes

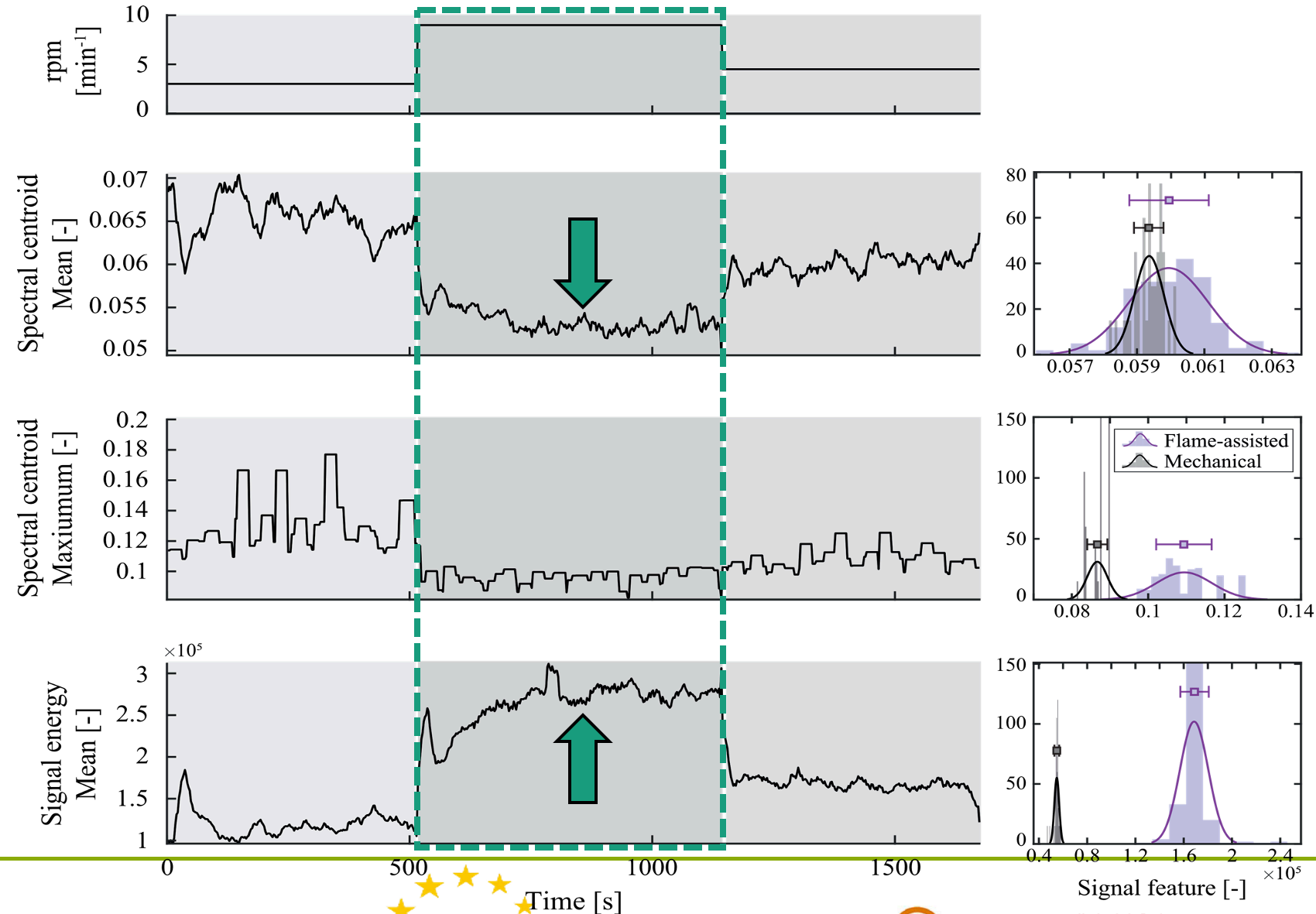
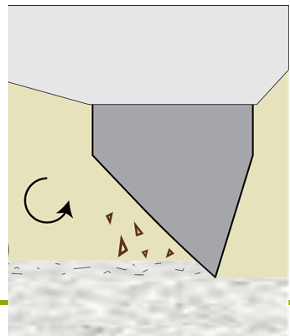
- **Flame Jet → high effect**  
**Effective Thermal spallation**
- **Mechanical drilling**





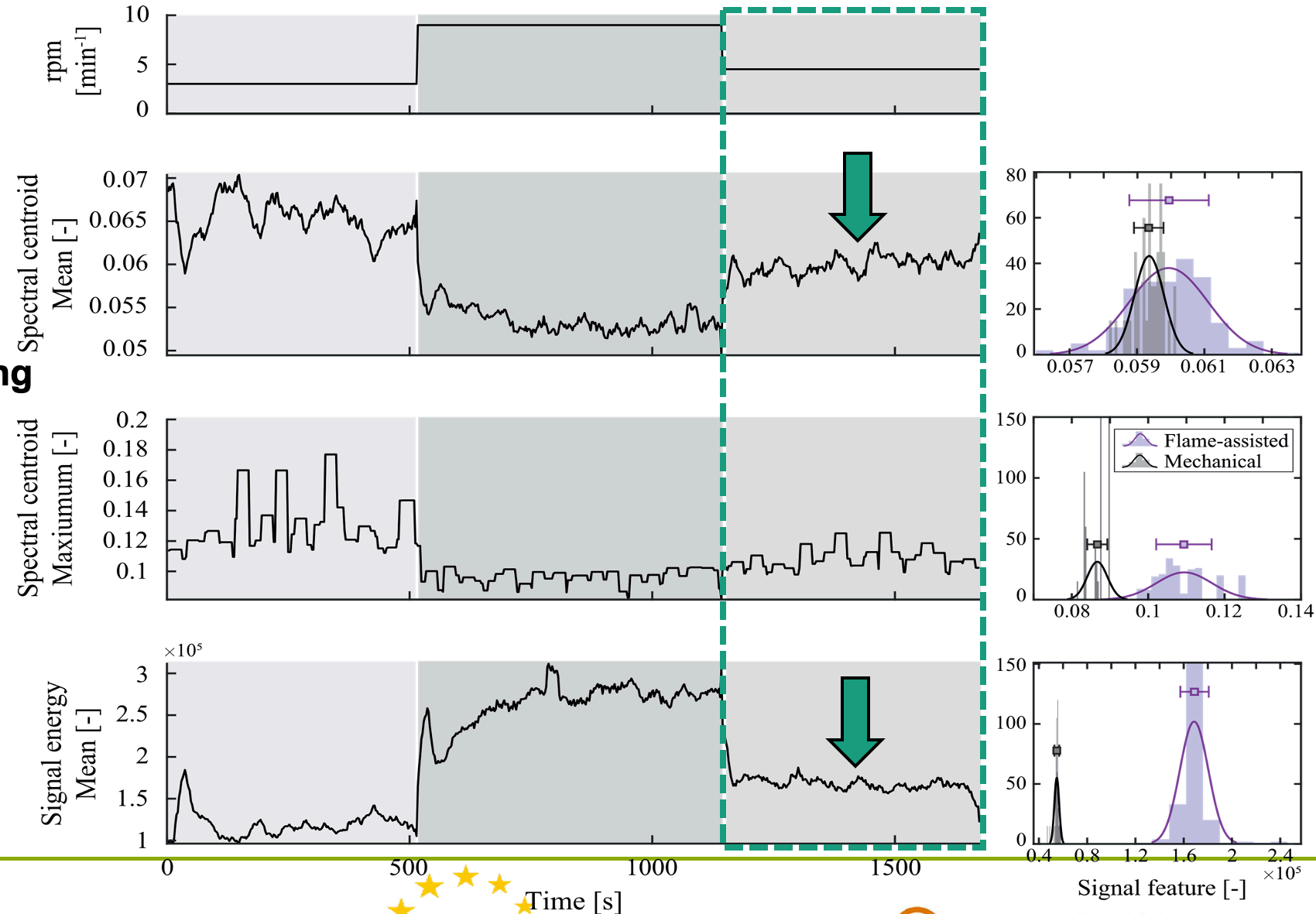
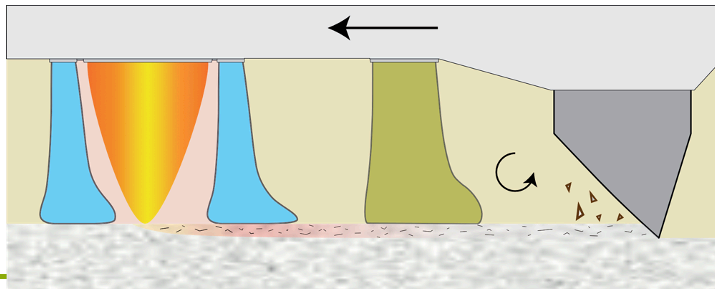
# Monitoring of any no-contact drilling processes

- Flame Jet → low effect  
Negligable Thermal spallation  
Negligable Thermal rock softening
- Mechanical drilling



# Monitoring of any no-contact drilling processes

- **Flame Jet → high effect**
- **Negligible Thermal spallation**
- **Effective Thermal rock softening**
- **Mechanical drilling**



# Dissemination activities

- ✓ GEOTHERM congress, Offenburg, February 2020
- ✓ DGMK Workshop, Wietze, Wintershall Dea, September 2019
- ✓ European Geothermal Congress (EGC), Den Haag, NL, June 2019
- ✓ EAGE congress, London, UK, June 2019
- ✓ 7th European Geothermal Workshop, Karlsruhe, Oct. 2019
- ✓ DEEP EGS Symposium, Orléans, November 2019
- ✓ Student Chapter Liaison / Baker Hughes visit, Celle, Nov. 2019
- ✓ Schlumberger Headquarter visit in Clamart, to discuss Mikro Jetting + drilling
- ✓ SPE Student Technical Congress November 2019 in Aachen
- ✓ Der Geothermie Kongress DGK, München, November 2019
- ✓ EGPD, Potsdam, DE, February 2019
- ✓ GEOTHERM congress, Offenburg, DE, February 2019
- ✓ SPE German section meeting, Aachen, DE, April 2019
- ✓ DGMK Workshop der Bohrfluid-Gruppe, Oelde, February 2019
- ✓ CAGE Project meeting at GZB, Bochum, June 2019
- ✓ AAPG 3. Crossover Workshop und conference , Switzerland, April 2019
- ✓ GDMB Workshop + meeting des Fachausschusses Geothermie, GZB, Bochum, June 2019
- ✓ Multi Sensor Acoustic Parameter Analysis (Mouse) System for Monitoring and Evaluation of Deep Drilling, Jetting, and Stimulation, World Geothermal congress, 2020
- ✓ High-Pressure Water Jet drilling technologies for EGR and Reservoir Stimulation to boost Geothermal Well Production, OIL GAS European Magazine
- ✓ A combined thermo-mechanical drilling technology for deep geothermal and hard rock reservoirs, Geothermics, <https://doi.org/10.1016/j.geothermics.2019.101771>
- ✓ Experimental evaluation of in-situ high pressure water jetting into sandstone and multiple rock types, Master thesis, Afshin Heidari, Examiners: Prof. Dr. -Ing. Jeanette Hussong, Dr. Shahin Jamali

# Conclusion

- AE analysis → **Complex** waveforms
- Multiple **noise** sources → in the drilling environment
- Need for extensive and **detailed analysis**
- signal features → **reducing signal complexity**
- Obtain information over different aspects of the process → using **multiple features**
- results useful for **future non-mechanical, contact free** drilling methods
- **Machine learning algorithms** → simplifying the analysis process
- Need to make MOUSE into **live measurement + display** of results

# Thank you for your attention

- This **work** has received funding in part from the European Union's Horizon 2020 research and innovation program under grant agreement and also from federal government GER / BMWi.

## Contacts:

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**Fraunhofer**  
IEG



INTERNATIONAL  
GEOTHERMAL  
CENTER BOCHUM

Hochschule Bochum  
Bochum University  
of Applied Sciences



# WP 1.5: Enhanced Radial Jet Drilling

## WP 1: Preparatory studies:

### WP 1.5: Enhanced Radial Jet Drilling (RDE)

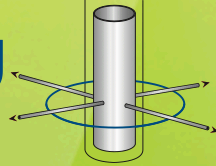
*Task 1.5.1: desk-study of performed Radial Jet Drilling operations (Geothermal and Oil & Gas)*

*Task 1.5.2: analysis of cores and cuttings in VITO (Balmatt) and Herentals area*

*Task 1.5.3: risk analysis Enhanced Radial Jet Drilling operations*

*Task 1.5.4: laboratory testing of rock samples corresponding to VITO and Herentals geology*

**radialdrilling**  
Geothermal Energy Optimization Technologies



# GEO THERMAL ENERGY OPTIMIZATION TECHNOLOGIES

[www.rdsgeothermal.com](http://www.rdsgeothermal.com)

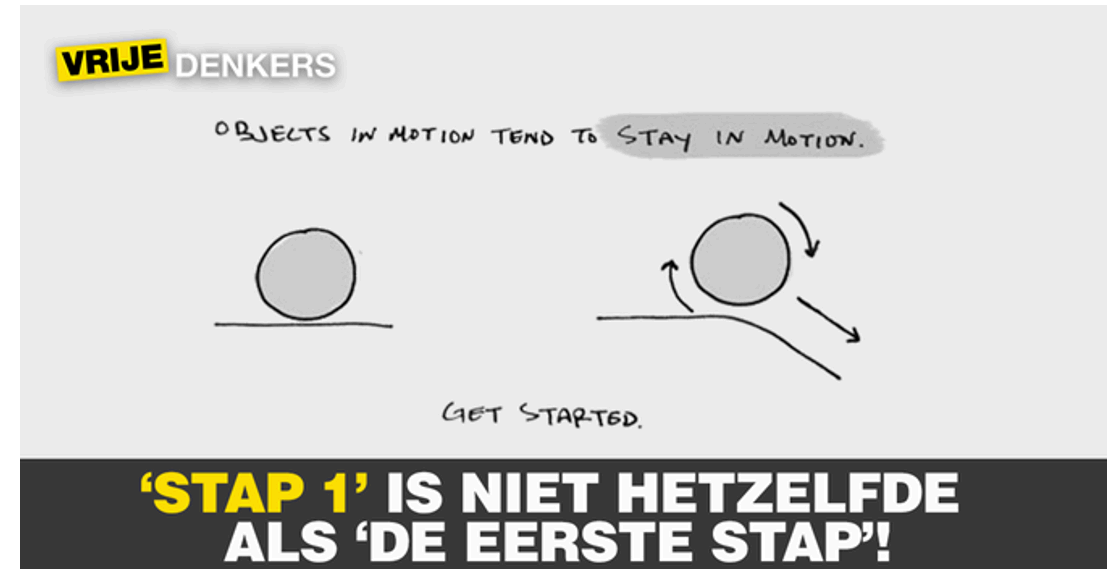




# Start the geothermal innovation process

with worldwide expertise and local support and know how.  
CAGE: Ronald den Boogert and Henk Jelsma, 9 September 2020

Funded by RVO and RDS

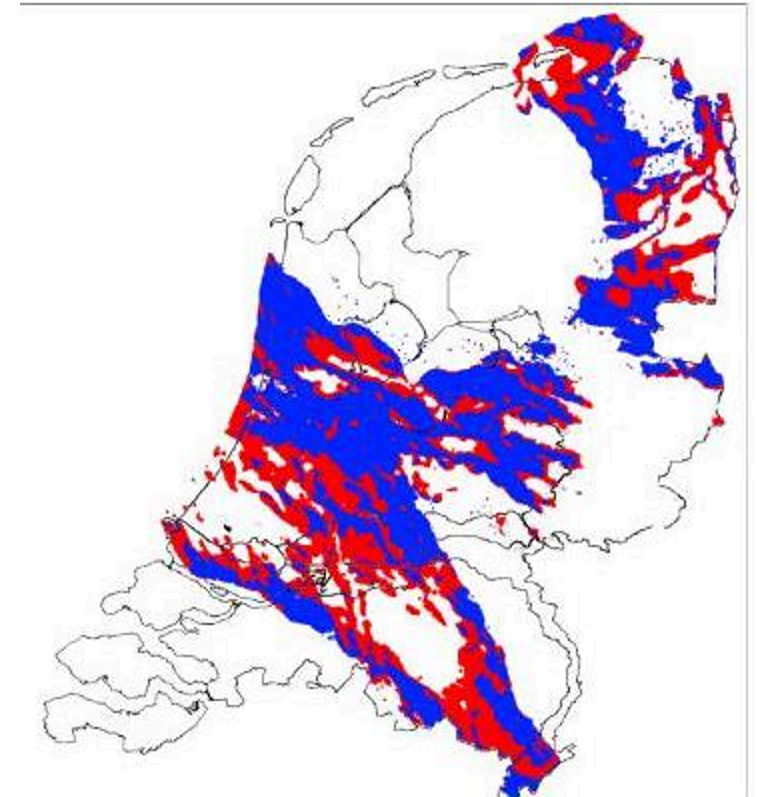


Rijksdienst voor Ondernemend  
Nederland



# Background

- Radial jetting has been successful in  $\pm 2000$  Oil & Gas industry projects, based on a large number of publications and interviews
- Radial jetting is not successful in four known geothermal projects.
- Supplier and owner of patents is very cooperative, but detailed data is not available.
- One consultant and one research institute estimate performance improvement between 30 and 300 % (see [www.moreheat.nl](http://www.moreheat.nl) and attached figure).
  - Red area's are potential new area's if stimulation is successful



# Intermediate conclusion, data-gap bigger than ever!

- Complicating factors
  - Not only data from jetting operation is limited but from the geothermal source as well. The following reasons may be applicable:
    - 0 to 8 years experience with geothermal operation instead of 80 years in Oil & Gas fields
    - 2 to 6 wells in operation in one field instead of 100 to 6000 in Oil & Gas fields
    - Normally no core samples available in geothermal wells
    - Waterflow in geothermal wells is 10 to 100 times bigger
- Opportunity
  - The geothermal reservoir is typically 70 to 700 meters thick instead of 2 to 7 meter in an oil field.



# Approach

- Team of local suppliers and international expertise have been working together to transfer, off the shelf solutions from other markets into one solution.
- Data-collection has been improved, made transparent and web based for online adjustments by worldwide experts.



# Update the plan 1, data collection streamlined

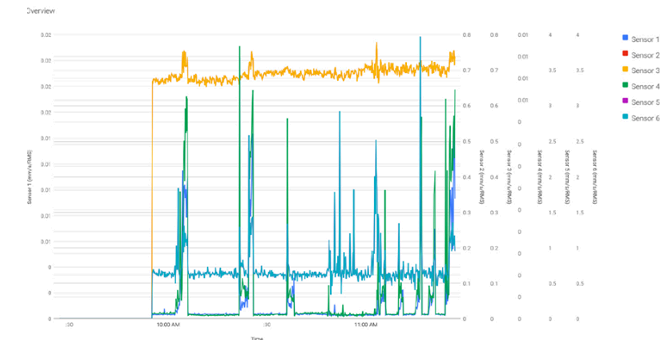
- With 70 to 700 meter target, the biggest risk is to miss the productive zone due limited feedback.
- Results, waste of 2 days per target level and risk of downhole damage!
  - Strategy
    - Soft and hardware is designed and put in place to add one day report with thousands of measurements of operating pressure, weight on bit, rate of penetration, water injection, used tools, vibration in tubing \*)
    - Second step vibrations will be measured downhole and hopefully connected to service read out or at least with memory \*)
    - Artificial Intelligence will automatically classify the operation.

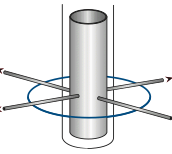
**\*) Status, ready for demonstration at VITO**



Date	Begin	End	Type
26/02/2020	09:27:00	11:27:00	5.5 Milling successful

Description Operator  
09:40 11:27 Mill. good Press differential, OP up to 200 KG





# Update the plan 2, new tool developed

- Second risk is to miss sufficient containment of the nozzle by entering the reservoir
  - Strategy
    - New tool will help to drill first few cm\*)
    - Larger and longer bit available but at this moment separate tubing run required (72 hours work for a single lateral)

**\*) Status ready for demonstration at VITO**



# Update the plan 3

- Third Risk, very low jetting speed due to nozzle \*) change every 15 minutes

	Oil Gas	Tight Carbonate (VITO)
Jetting time	45 minutes	Hours
HCL concentration	15 % few minutes	30 % few hours
Temperature	40 to 80 degrees Celsius	135 degrees Celsius
Estimated lifetime standard nozzle	60 minutes	15 minutes
Time to change nozzle	4 hours	6 hours



**\*) Status ready for demonstration at VITO**



# Activity

- ## Results

- 



# Cage Planning

- June 2020
  - Finalize the well program for Vito 🧑
  - Submit quarry samples to Houston 🧑
- August 2020
  - Test datalogger, software and tester individually 🧑
- September 2020
  - Test total system, datalogger and equipment (except injector head) in the field. **scheduled 14 – 28 September**
  - Test injector head in workshop **scheduled 18 – 28 September**
- October November 2020
  - Run demonstration at Vito, **scheduled and prepared for 4 October 2020**
    - Run datalogger
    - Run downhole vibration sensor (Fraunhofer)
    - Run microdrill
    - Run long life nozzle
    - Run 4000 meter length
- November 2020
  - Injection test
  - Reporting and knowledge transfer





# WP 1.6: Well design

<b>WP 1: Preparatory studies:</b>
<b>WP 1.6: Well design (Mijnwater &amp; third party Well Engineering Partners)</b>
<i>Task 1.6.1: determining the optimal well location(s)</i>
<i>Task 1.6.2: final well design(s)</i>



# CAGE

**Composite casing and the Acceleration of Geothermal Energy**



# Mijnwater – HH3a feasible and necessary

The HH3a well and the CAGE project:

- With the current and almost-established contracts, Mijnwater will no longer be able to meet the demand in the relatively short term.
- Therefore it is absolutely necessary to realize at least one additional geothermal well.
- The HH3a well will be installed and completed before the end of 2021.



# Mijnwater – HH3a well

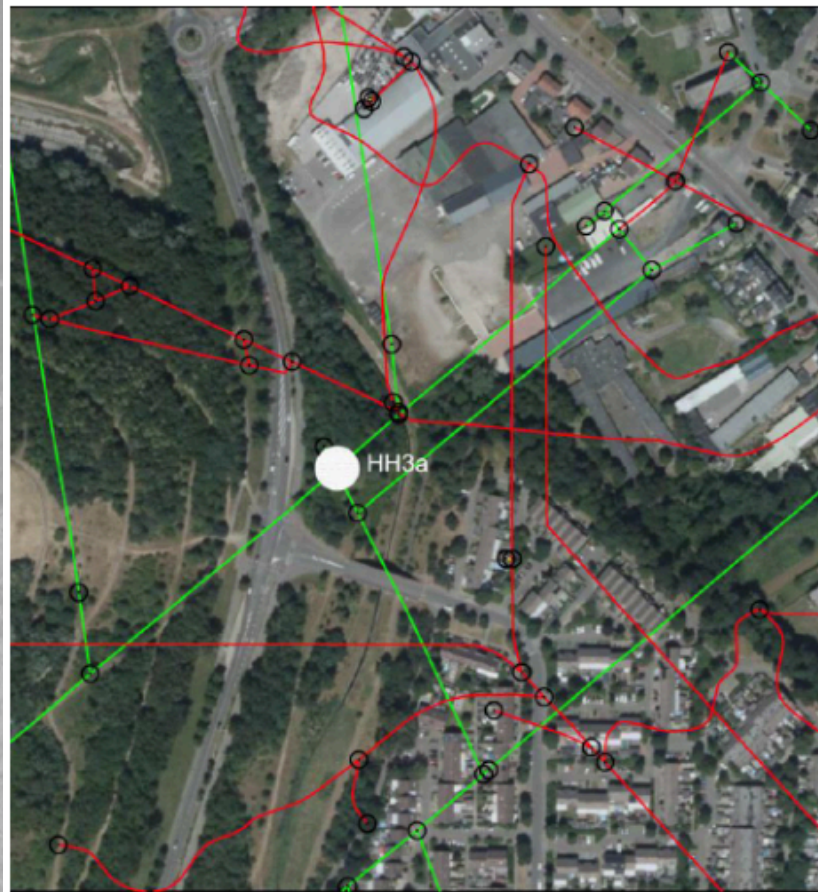
Formal name of the HH3a well according to State Supervision of Mines will be:  
**HEH-GT-03**

The order of the actions to be completed is as follows:

- Measure location, discuss conditions (purchase or rental contract) with landowner —> Full MER probably not necessary
- Permits (MER, WABO, drilling and surface installations, building permit(s) pump house and pump cellar, ...)
- Final well design
- Request for Quotation of Huisman GEO (turn-key?)
- Purchase Order from Mijnwater for installation HH3a



# Mijnwater – HH3a well location





# Mijnwater – HH3a well design (old & new)

## Well design #2 (700m)

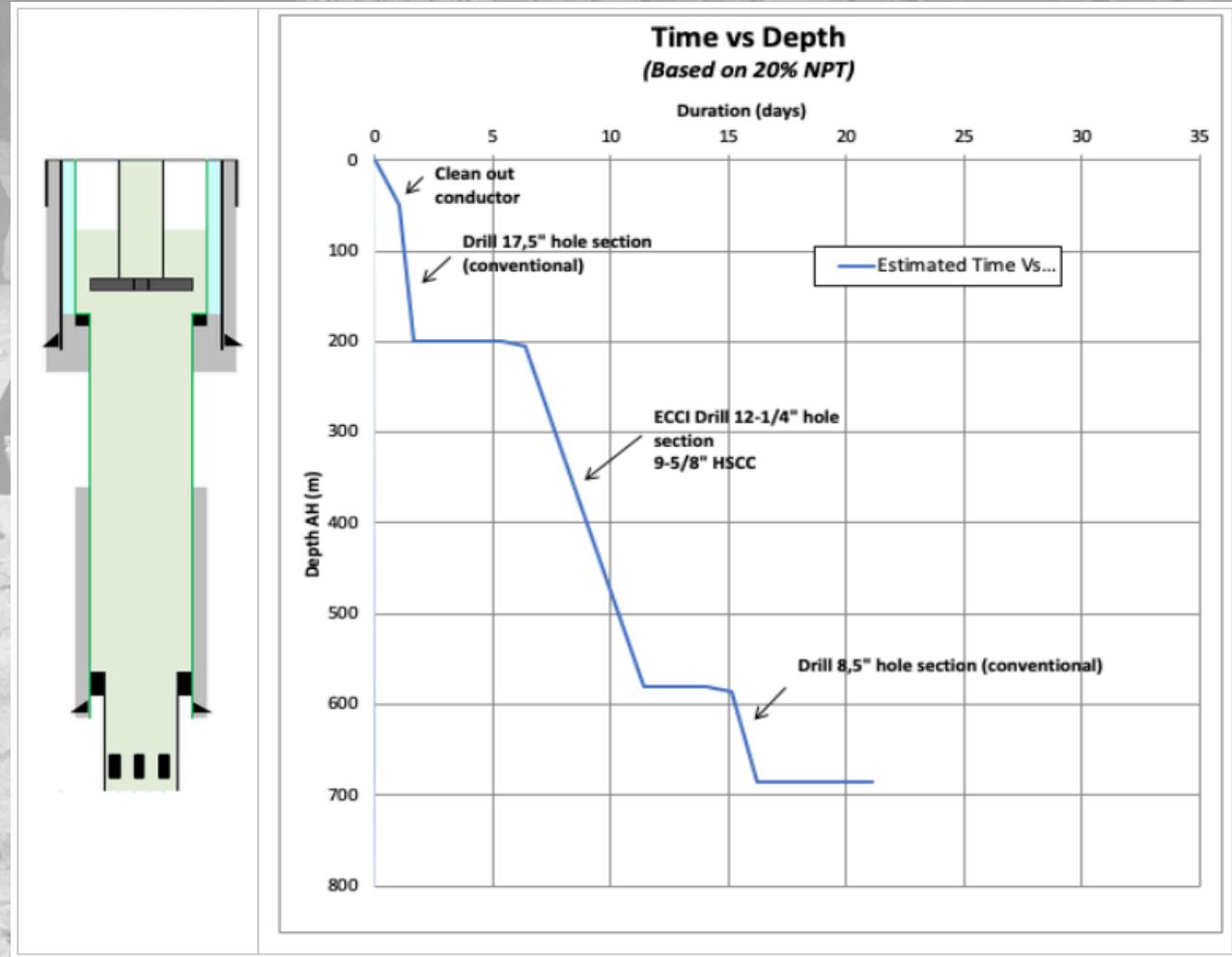
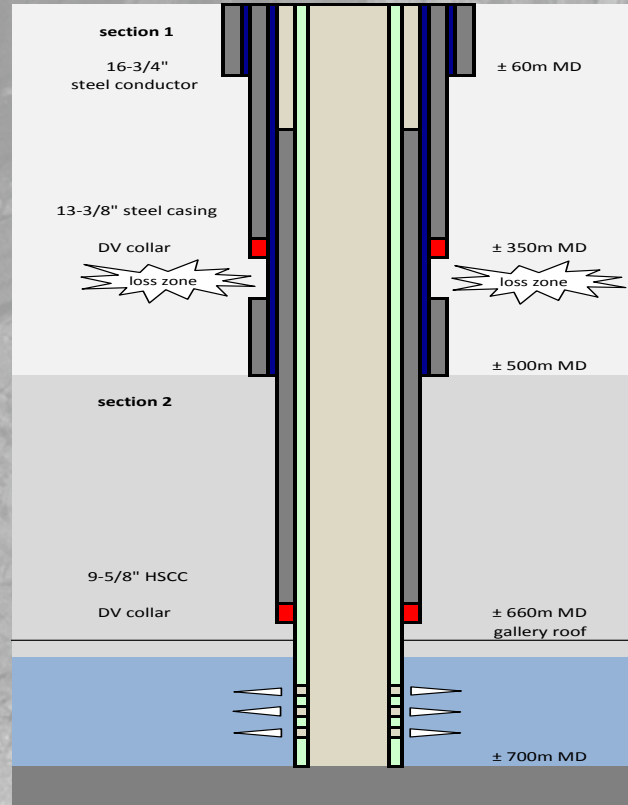
(enables crane-based ECCI & airlift technology)

### section 1:

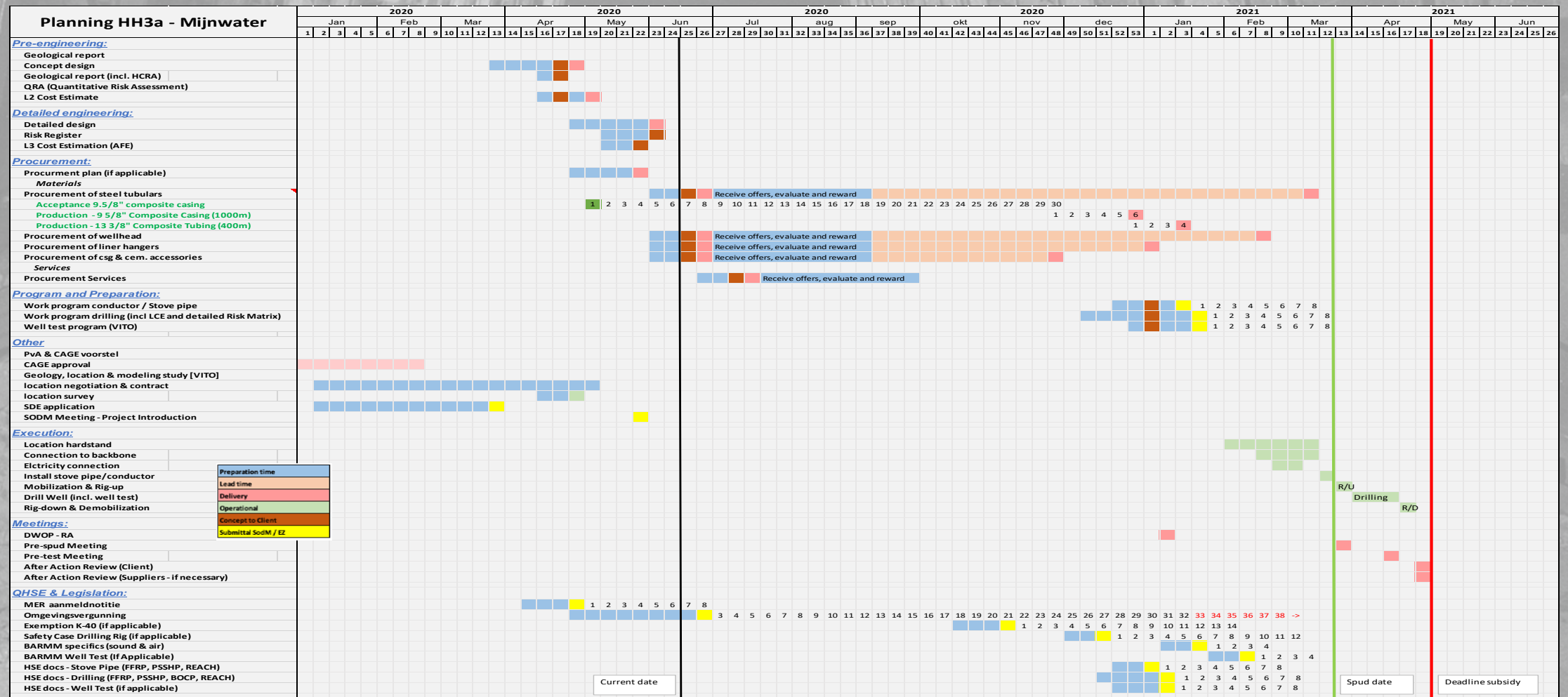
16-3/4" steel conductor (blue)  
13-3/8" steel casing installed with ECI technology (bleu)

### section 2:

9-5/8" HSCC installed with ECCI technology (light green)



# Mijnwater – HH3a well planning



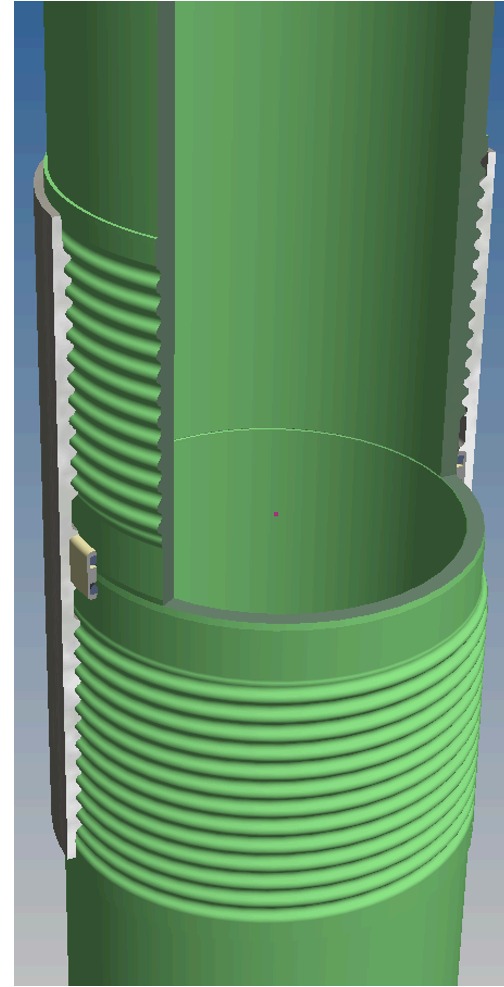
# WP 2: Development of HSCC mechanical connection

<b>WP 2: Development of full-composite mechanical connection (HWT)</b>
WP 2.1: Development phase
WP 2.2: HSCC mechanical connection - test phase
WP 2.3: HSCC Acceptance Program, focussed on mechanical connection → Not yet started



# CAGE

## AKIET - HIGH STRENGTH COMPOSITE TUBULARS



AUGUST 2020

CAGE - AKIET – HSCT



**VALUE PROPOSITION**

**RESEARCH AND DEVELOPMENT**

**PRODUCT DEFINITION**

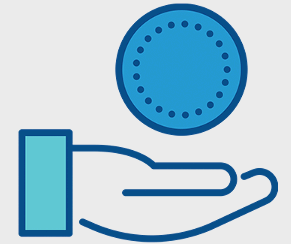
**ROADMAP**

**TRACK RECORD**

# VALUE PROPOSITION

## All General benefits of Glass Fiber Reinforced Epoxy pipe

- ✓ No Corrosion
- ✓ No Scaling
- ✓ Naturally inert to Chemical Attack
- ✓ 80% Lighter than Steel
- ✓ Transparent to Electromagnetic Logging (*Metal connections excluded*)



## With invaluable distinctive AKIET features

- ✓ **Designed and tested to endure hot & wet downhole conditions**  
Systematic short- and long term testing in saturated and thermally elevated conditions.
- ✓ **Very slender and robust threaded connection (patented)**  
Maximum ID and thus the best pump efficiency in the available borehole.  
High axial ratings and multiple MU/BO cycles possible.
- ✓ **Completely internal flush connections**  
Prevent turbulence and subsequent erosion and losses.
- ✓ **Superior production process**  
Akiet's surface finish is super smooth providing the best pump efficiency.  
Glass fibers can be placed in the optimal directions to coop with hoop- and axial stresses.  
Completely void free, making the product stronger and less vulnerable to chemical attack than filament wound GRE.



# RESEARCH & DEVELOPMENT

## CHALLENGES

### 1. Challenges for Composite downhole tubulars

- **Composites behave fundamentally different than steels**
  - Anisotropic (also an advantage)
  - Temperature sensitivity (Glass transition temperature of resins)
  - Material aging
- **Lack of codes / standards / recommended practices for design and qualification**
  - API 5C2/C3 Failure envelope approach for steel not applicable
  - Industry acceptance > working with composites is different than usual



### 2. Challenges former product

- **Glued connection**
  - Temperature rating lower than pipe
  - Impracticality on the drill floor
- **Production process**
  - Control, consistency, QA/QC



# RESEARCH & DEVELOPMENT

## MATERIAL RESEARCH

### Fundamental material research

	Stage 0: Raw material	Stage 1: Micro level	Stage 2: Meso level	Stage 3: Macro level
Manufacturing Equipment	Casting mould	Sample equipment (Vac. Inf. and Ring)	2.5m machine	12m machine
Function	<ol style="list-style-type: none"> <li>1. Manufacturing of samples for ASTM testing and testing</li> <li>2. Determining properties of resin: <ol style="list-style-type: none"> <li>1. Strain at break</li> <li>2. Modules of elasticity</li> <li>3. Creep</li> </ol> </li> <li>3. Incorporating properties in modelling</li> </ol>	<ol style="list-style-type: none"> <li>1. Manufacturing of samples for ASTM testing and testing</li> <li>2. Manufacturing of rings</li> <li>3. Understanding of impregnation process</li> <li>4. Determining properties of resin: <ol style="list-style-type: none"> <li>1. Strain at break</li> <li>2. Modules of elasticity</li> <li>3. Creep</li> </ol> </li> <li>5. Incorporating properties in modelling</li> </ol>	<ol style="list-style-type: none"> <li>1. Manufacturing of samples and testing</li> <li>2. Model comparison</li> <li>3. Updating model</li> </ol>	<ol style="list-style-type: none"> <li>1. Manufacturing of samples and testing</li> <li>2. Model comparison</li> <li>3. Updating model</li> </ol>

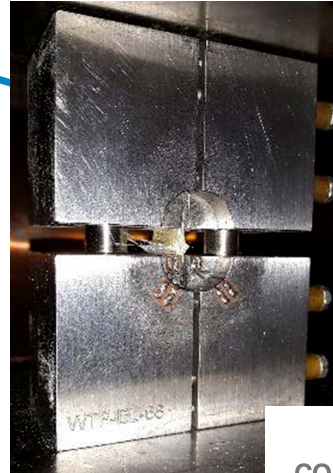
# RESEARCH & DEVELOPMENT

## MATERIAL RESEARCH

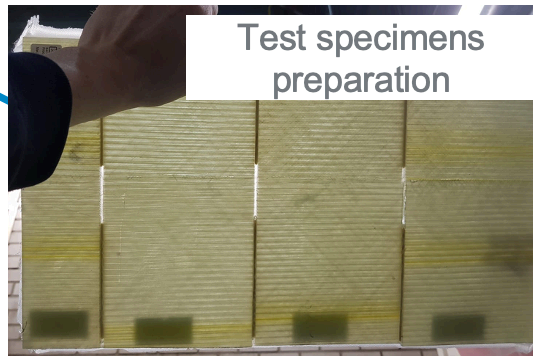
Resin testing and selection



Glass testing and selection



In-plane  
compression



Test specimens  
preparation

### Research goal

Understanding material behavior for long term loading conditions (30y) in hot (85°C) and submerged environment.



In-plane  
Tension



# RESEARCH & DEVELOPMENT

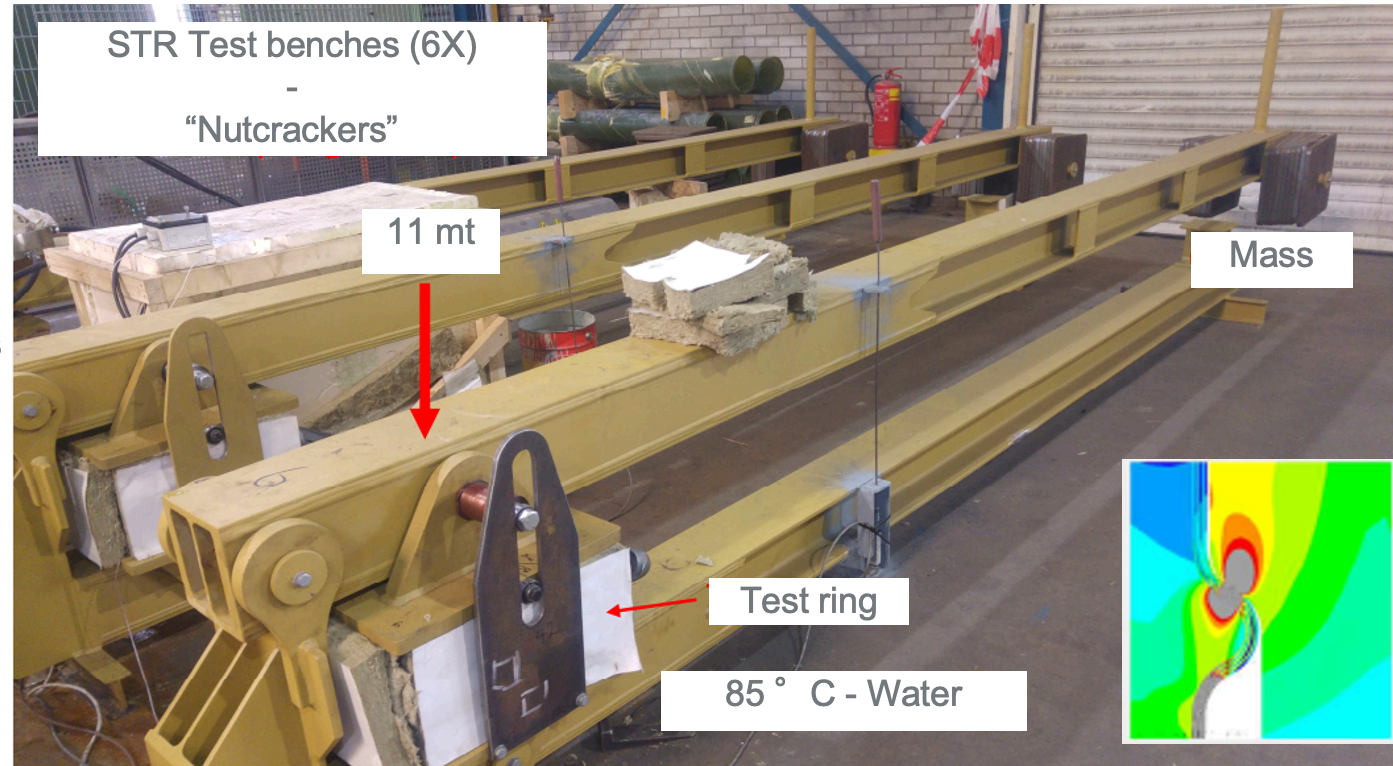
## CONNECTION DEVELOPMENT

### Research goal

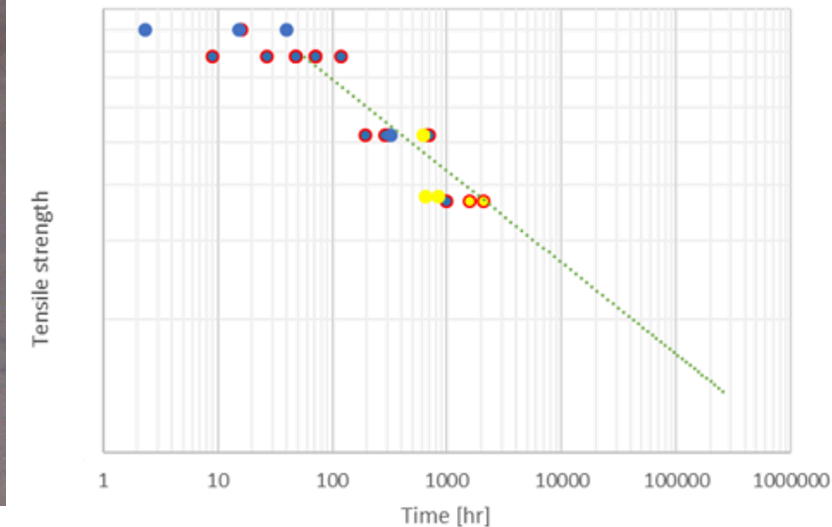
Understanding material behavior for long term loading conditions (30y) in hot (85°C) and submerged environment.

### Extensive test program at elevated temperature in wet conditions

- Short-term test (failure within minutes)
- Mid-term test (failure within 24hr to 10.000hr)

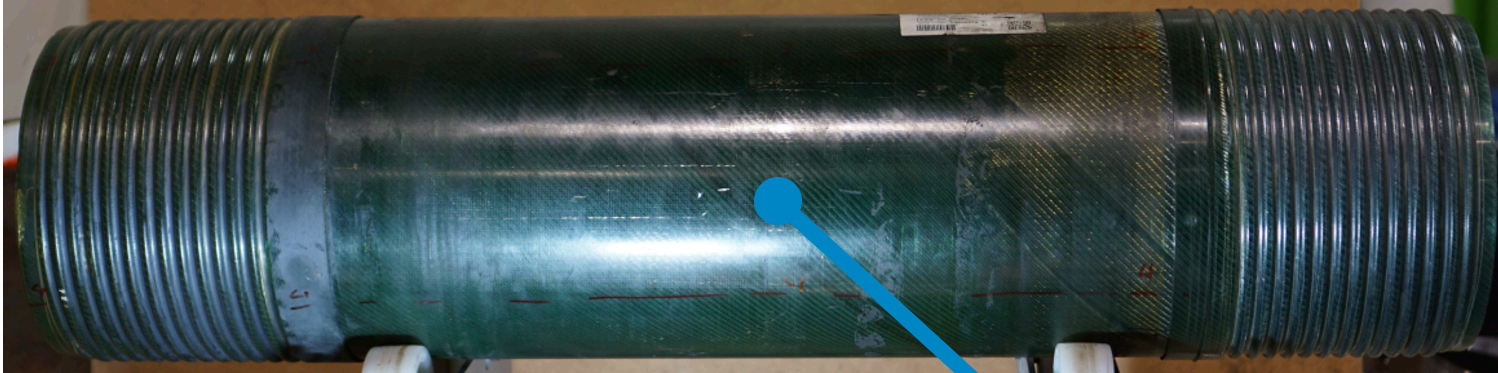


Example of regression line (Log – Log diagram)



# RESEARCH & DEVELOPMENT

## CONNECTION DEVELOPMENT



Full scale 9 5/8" connection on short tube

**Research goal**  
Full scale validation



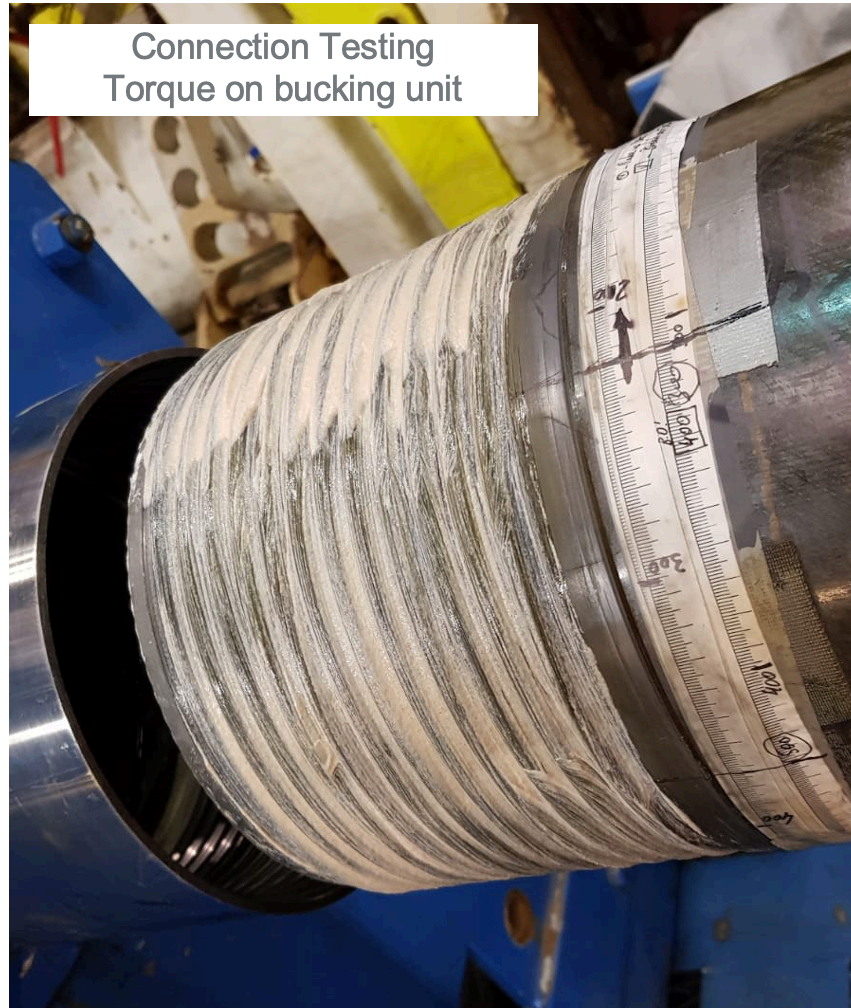
Connection including collars in hot wet bucket



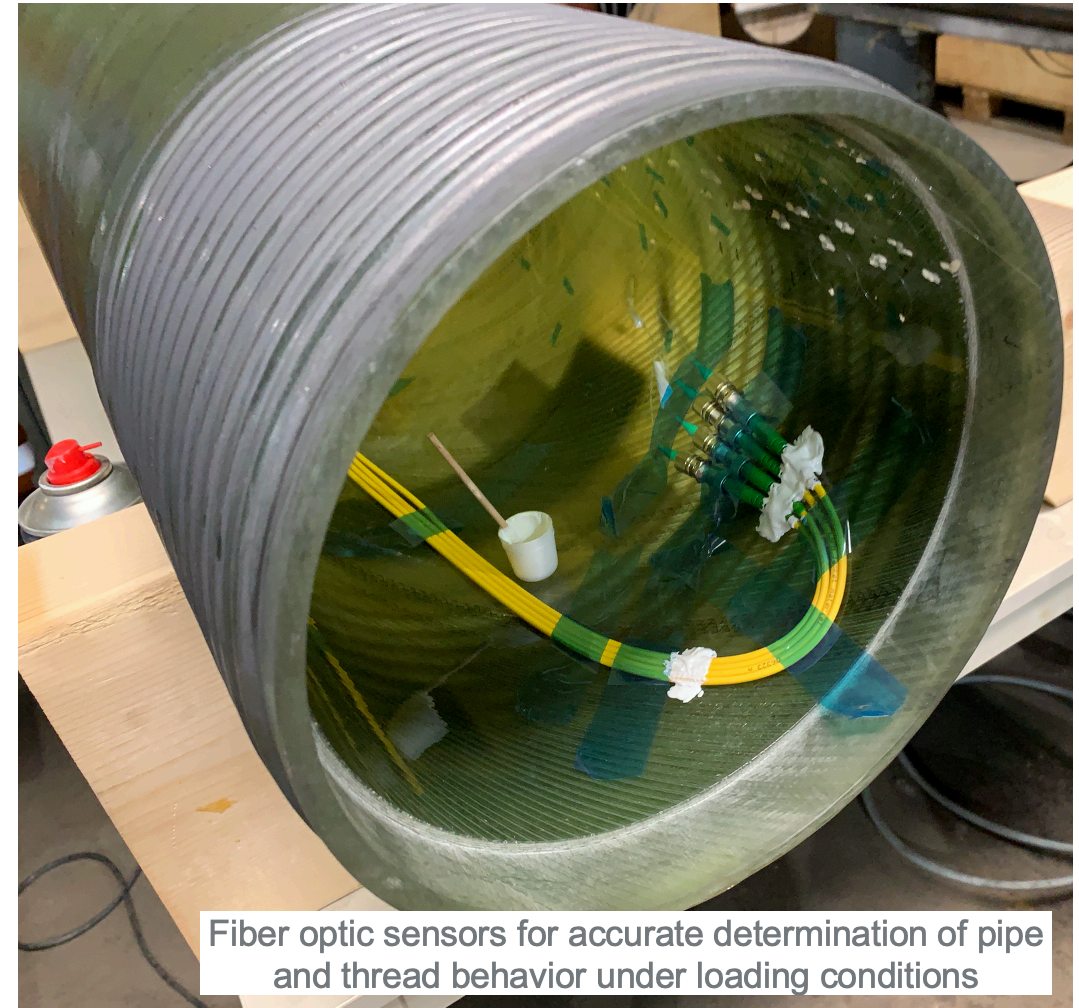


# RESEARCH & DEVELOPMENT

## CONNECTION DEVELOPMENT



CAGE - AKIET – HSCT



# RESEARCH & DEVELOPMENT

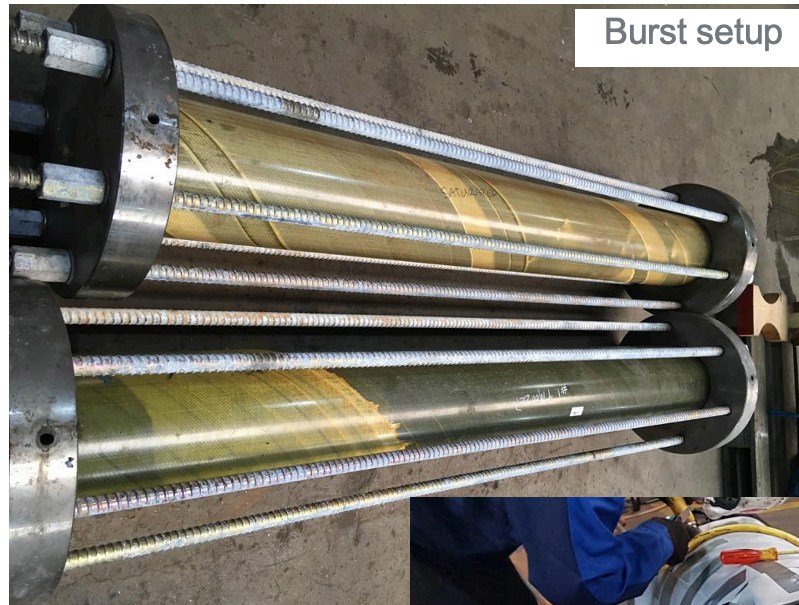
## FULL SCALE PIPE TESTING

Saturating test pieces

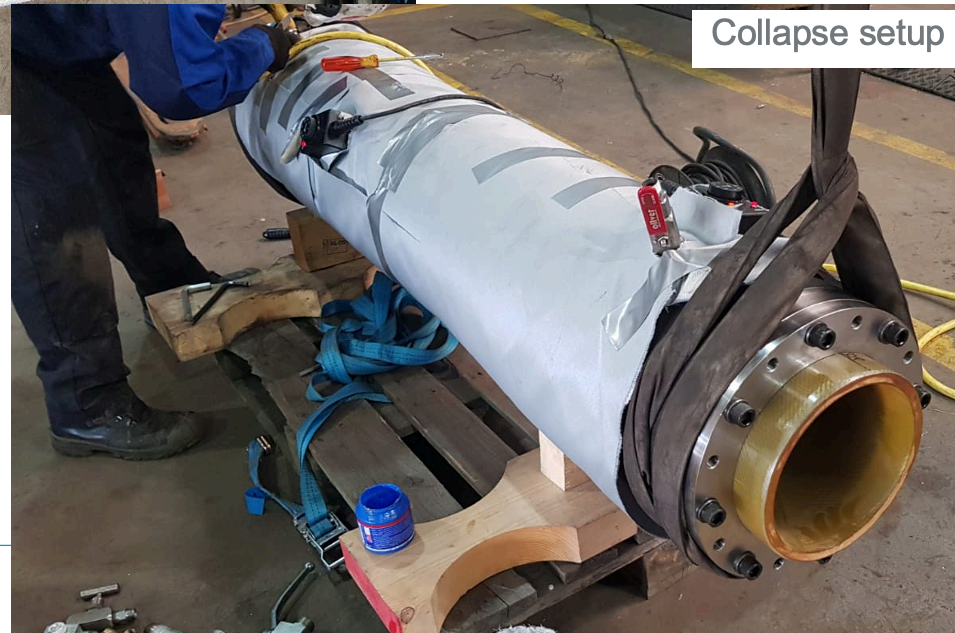


CAGE - AKIET – HSCT

Burst setup



Collapse setup



Burst Failure





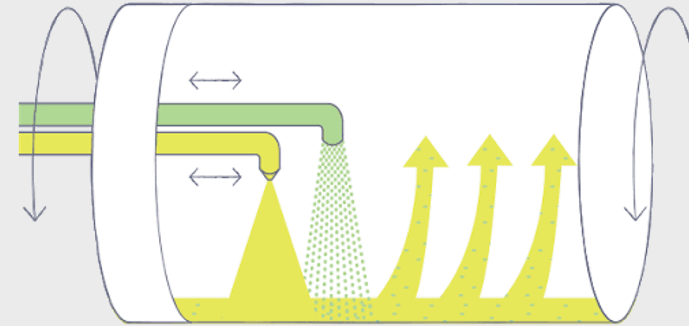
# RESEARCH & DEVELOPMENT

## PRODUCTION PROCESS IMPROVEMENT

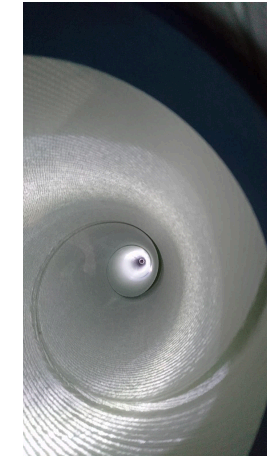
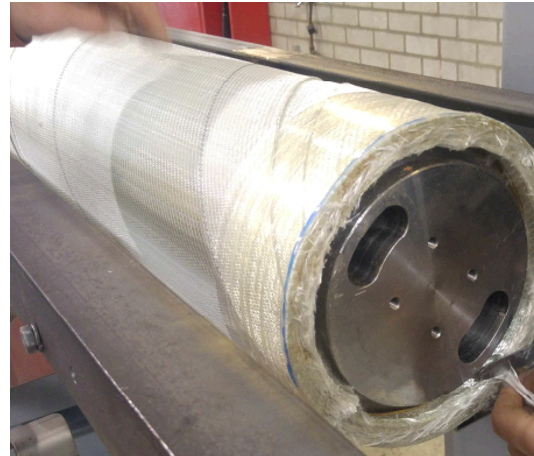
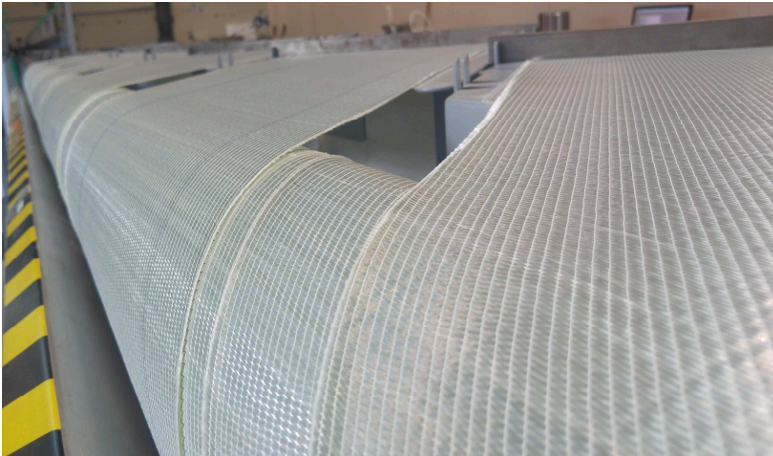
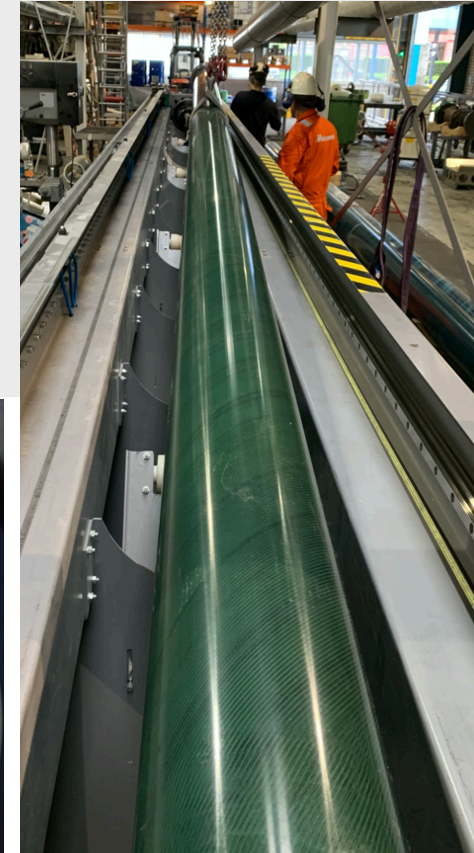
### Production

- **Parameters**
  - Temperature control
  - Layup control
  - Centrifuge improvements
  - Injection procedure
  - Full logging of process parameters
- **QC / QA process flow**
  - Raw materials
  - Traceability
  - Qualification program

Centrifugal Casting – example



Source: Compositelab.com



CAGE - AKIET – HSCT

# PRODUCT DEFINITION

## DESIGN & DIMENSIONS

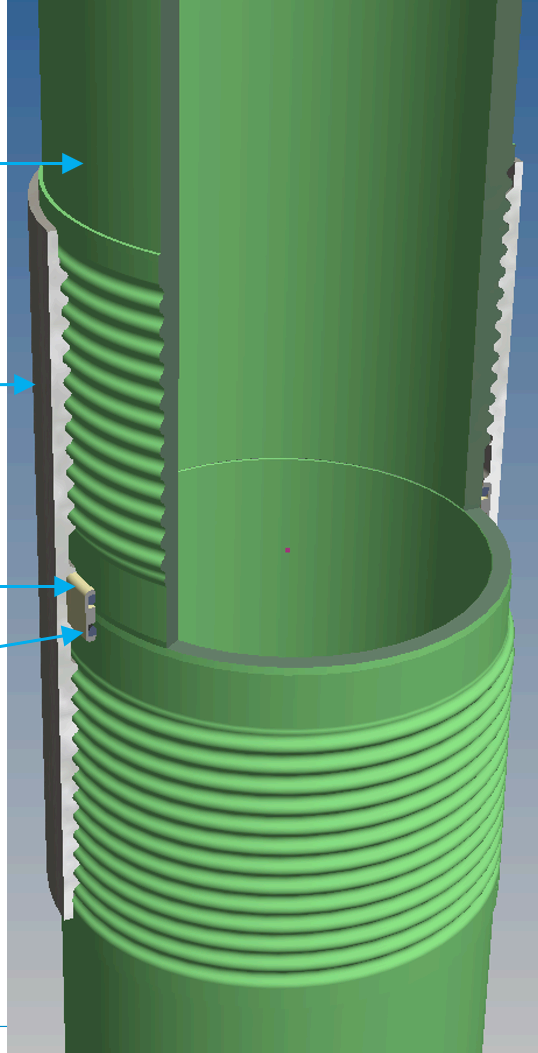
AKIET GRE Pipe

Steel Collar

Seal Carrier

Elastomer Seal

CAGE - AKIET – HSCT

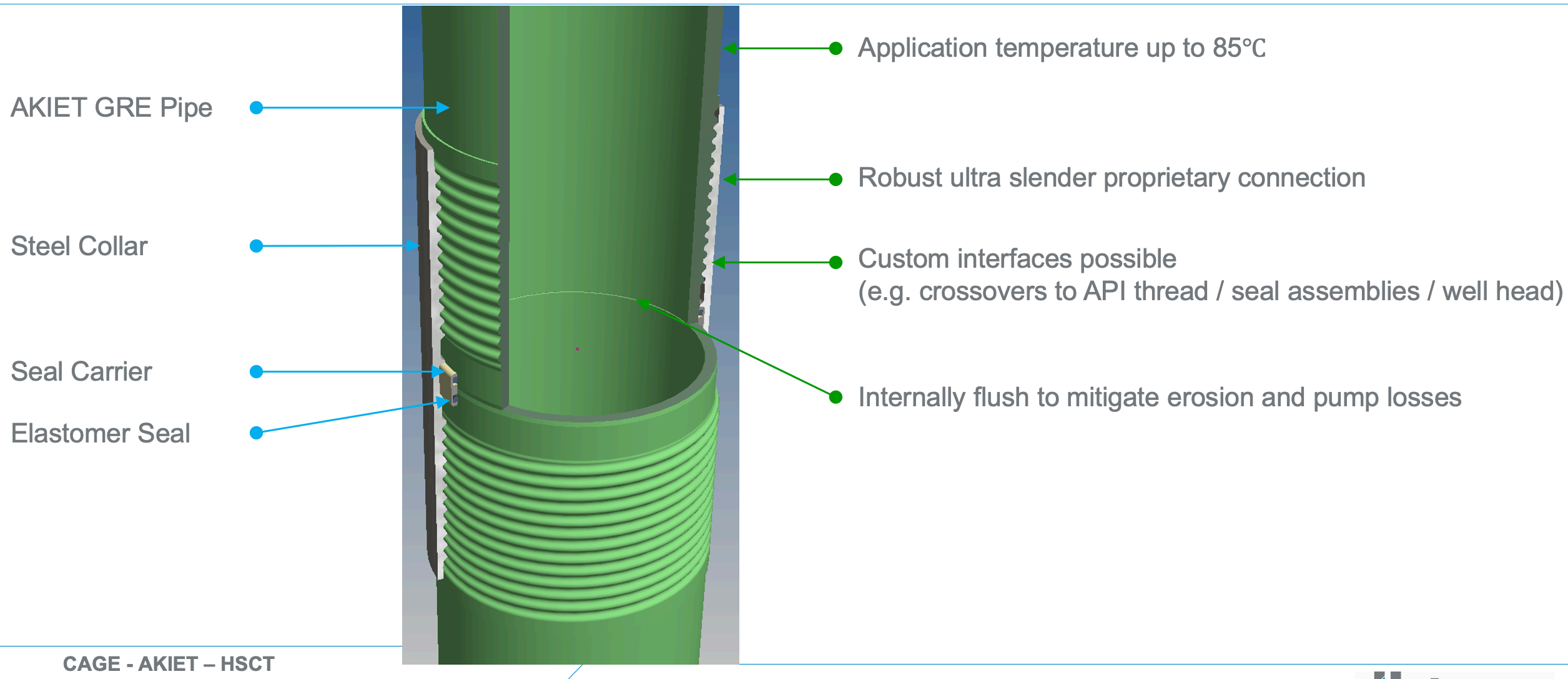


Patented  
connection



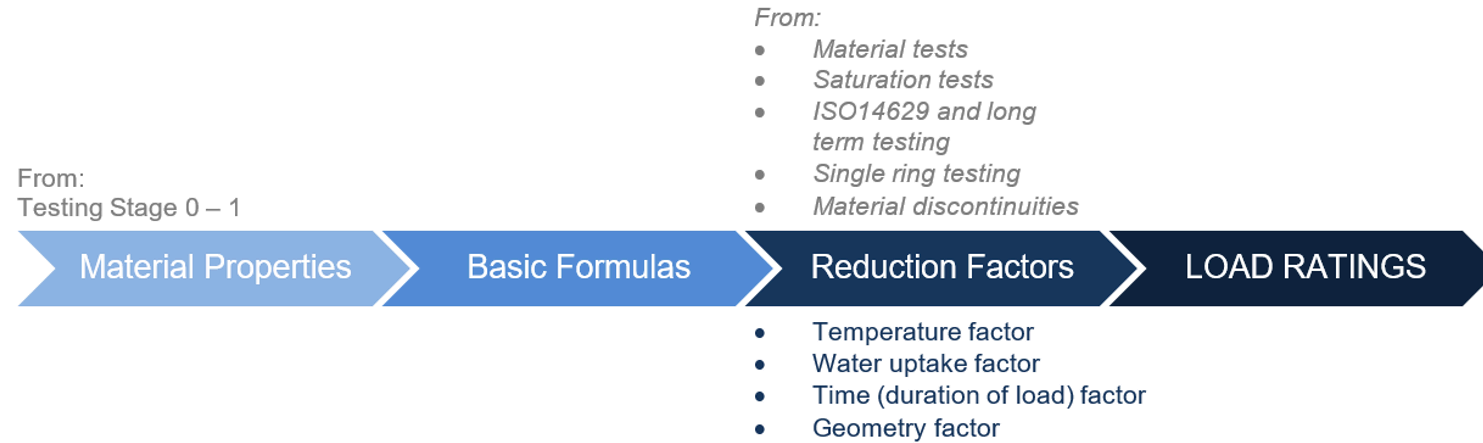
# PRODUCT DEFINITION

## DESIGN & DIMENSIONS



# PRODUCT DEFINITION

## LOAD RATINGS

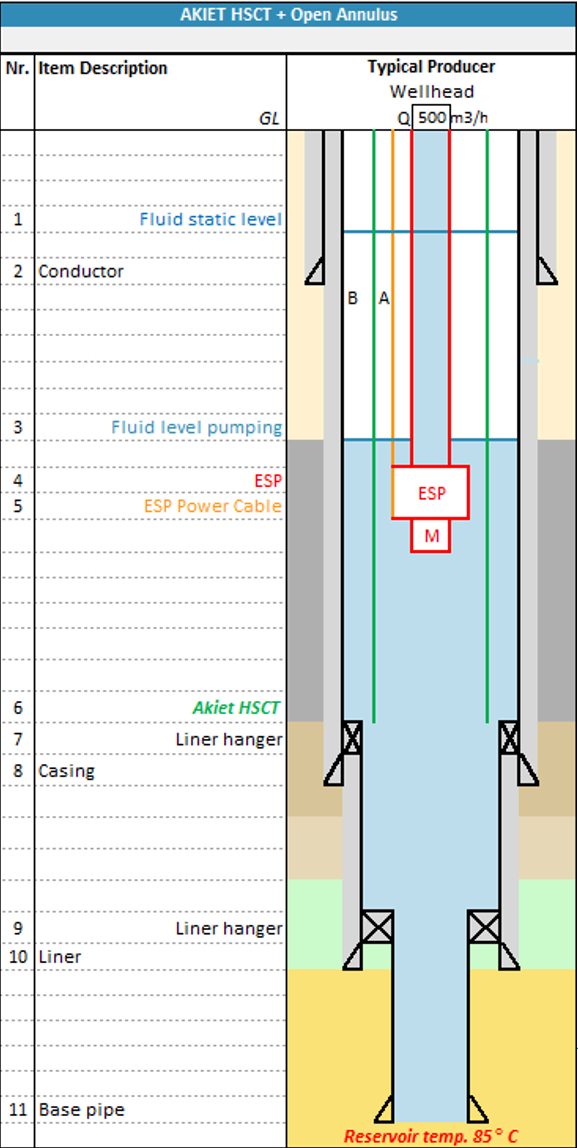
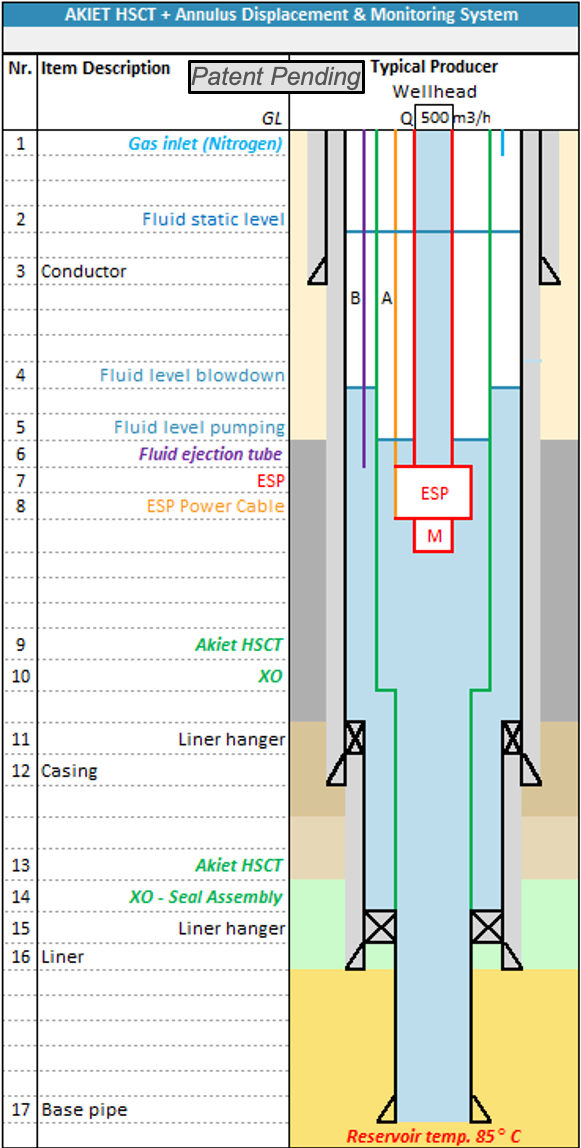
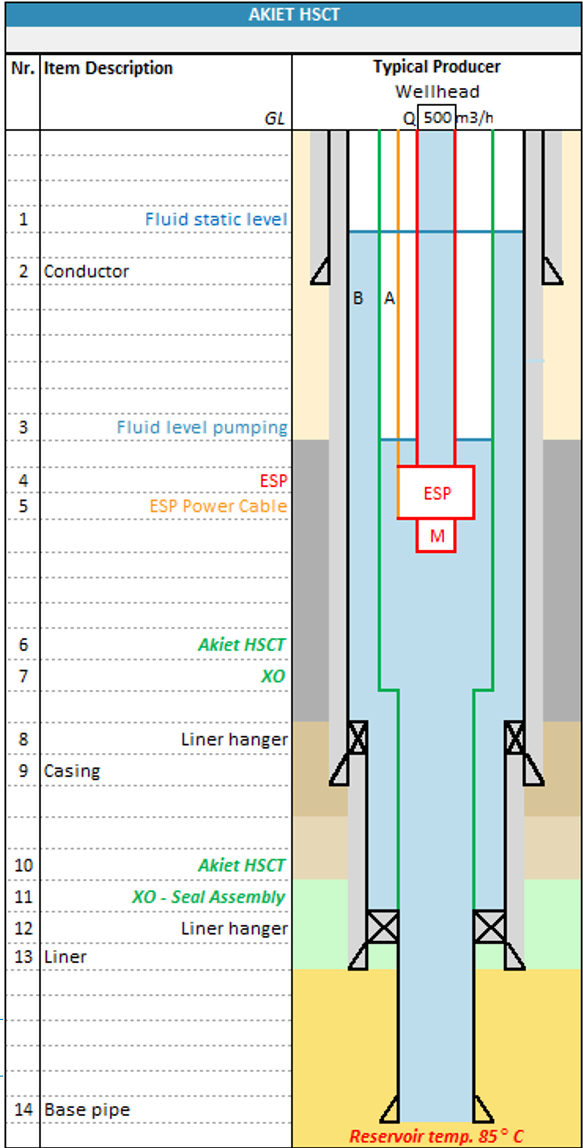


# APPLICATIONS

## GEOHERMAL – EXAMPLES – TUBING

Crane based installation

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# APPLICATIONS

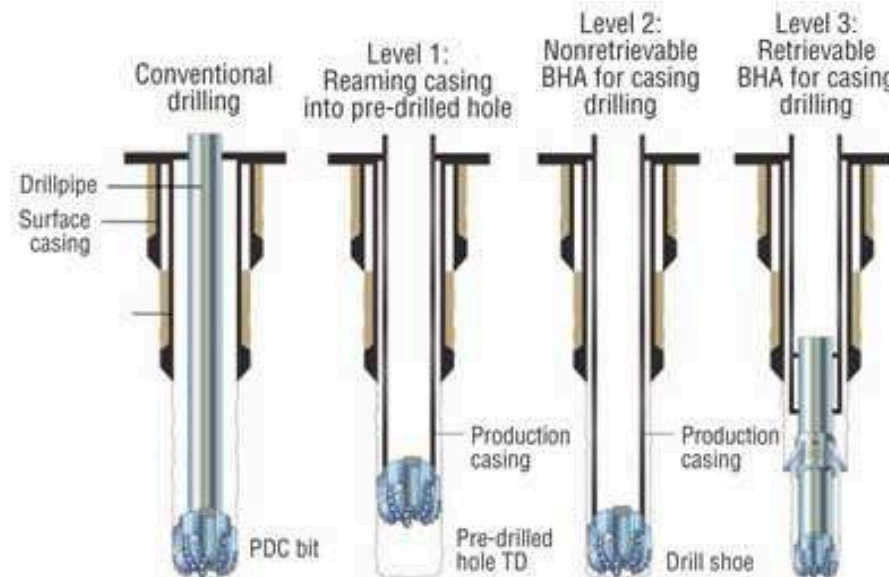
## HT-(A)TES – EXAMPLE – CASING

CAGE Concept well design by:



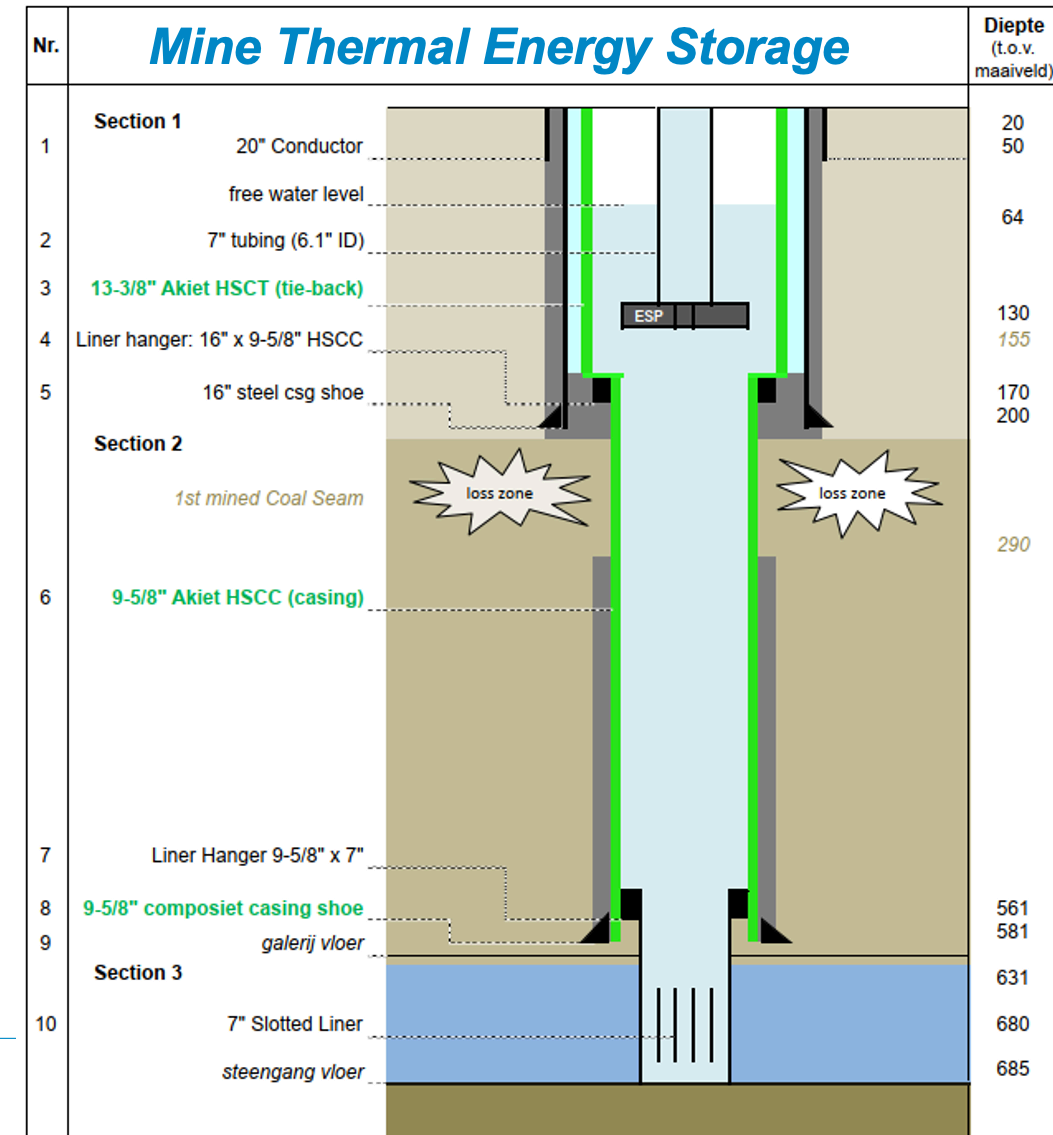
### Enhanced Composite Casing Installation (ECCI) Technology

- Casing While Drilling – Level 3
- Huisman ECI System (Enhanced Casing Installation)
- Composite casing



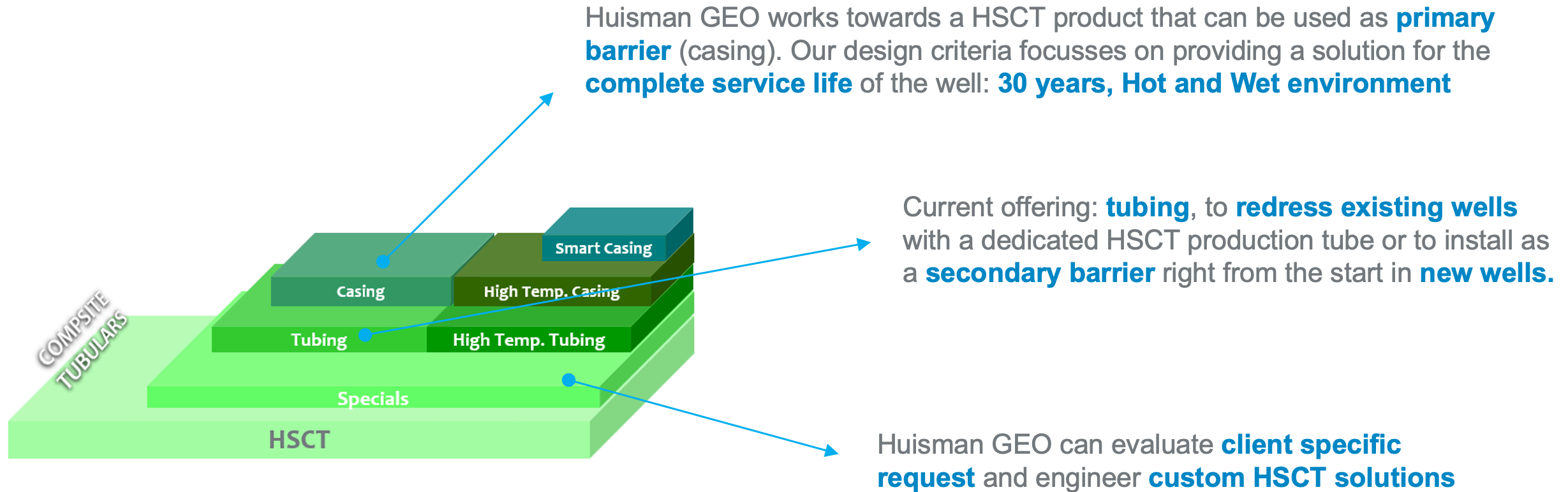
Courtesy of Schlumberger

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# HSCT - TECHNOLOGY PLATFORM



# TRACK RECORD



## AKIET CASING in Observation Well

- Oil & Gas industry
- Location: Zalzala, Sultanate of Oman
- Purpose: Evaluate injection of miscible gas in the reservoir (NMR)
- 7" Akiet liner installed in 8 3/8" hole (as part of a steel liner)
- Quantity 150m
- Vertical depth 5000m

# TRACK RECORD



## AKIET tubing in Geothermal Injector

- Location: Denmark, Thisted
- Purpose: Corrosion resistance and friction loss mitigation
- 10.6" Akiet tie-back liner installed from -1100 to 0m inside 13 3/8" casing.





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# WP 3 & WP 4

WP 3: Demonstration of shallow GE concept & new technology → Not yet started / in preparation
WP 4: Management, Coordination & Dissemination
Critical path
Financial progress
HSE issues

# CAGE-project

The CAGE-project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731117



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