Source: FH Aachen/www.lichtographie.de

ICE MOLE
Subsurface Icecraft

Prototype Development and Testing of a Subsurface Icecraft

Antarctic Science Symposium
Madison (WI), USA
27. April 2011

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IceMole
Principle of Operations

IceMole
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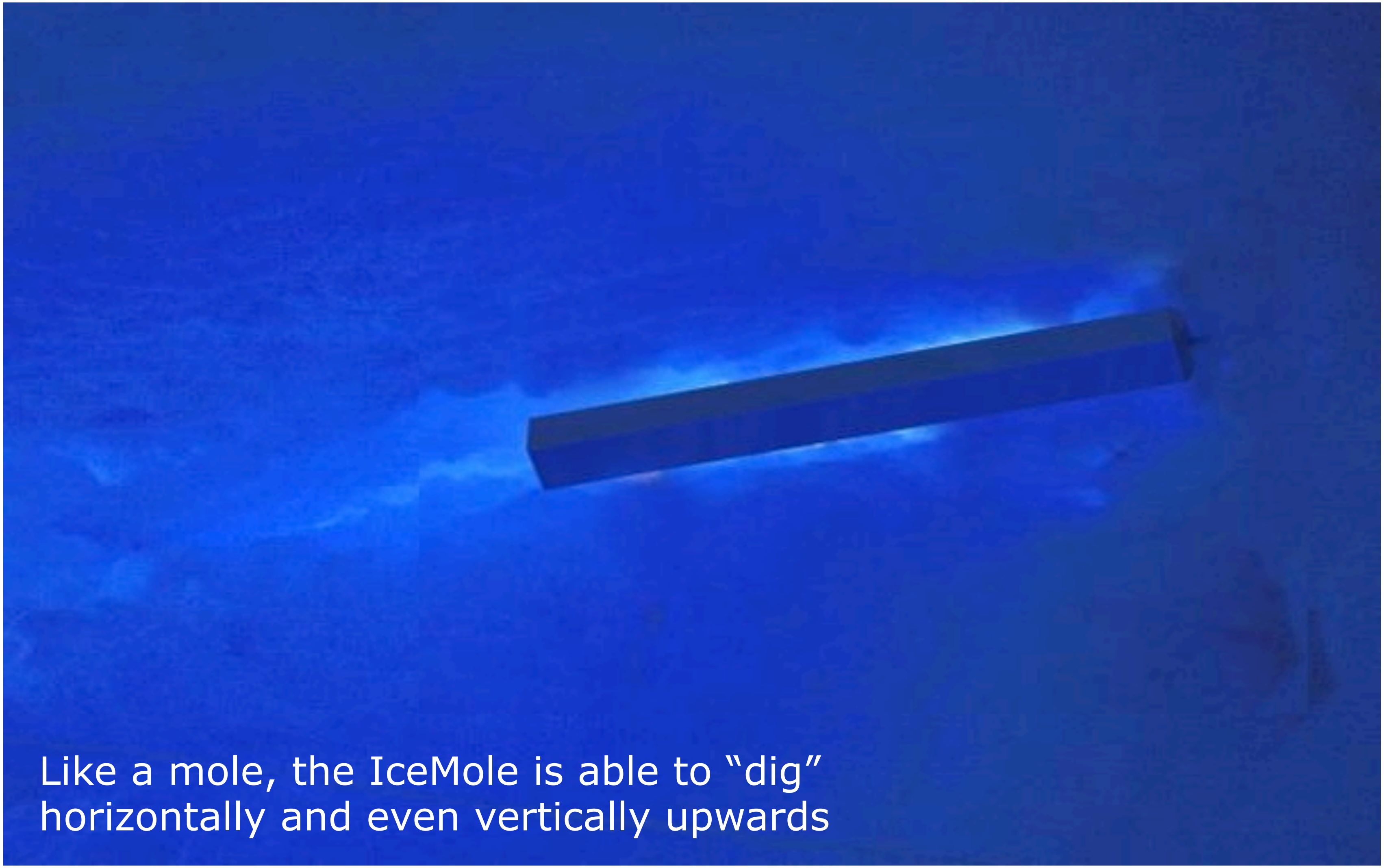


IceMole
Principle of Operations

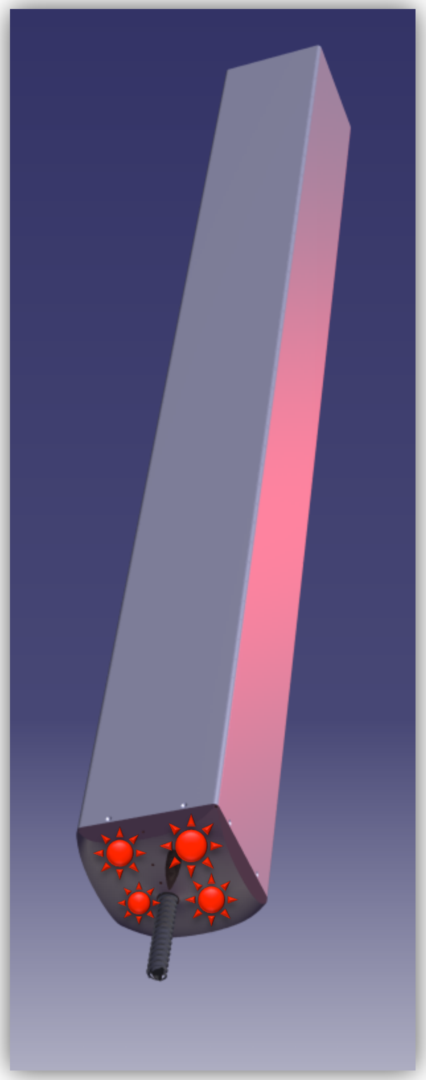
> Forward motion ("digging") with combined melting head and ice screw
(The ice screw is essential for digging horizontally and vertically up against gravity)

> Maneuverability (cornering ability) in ice by differential heating

> Robust mechanics

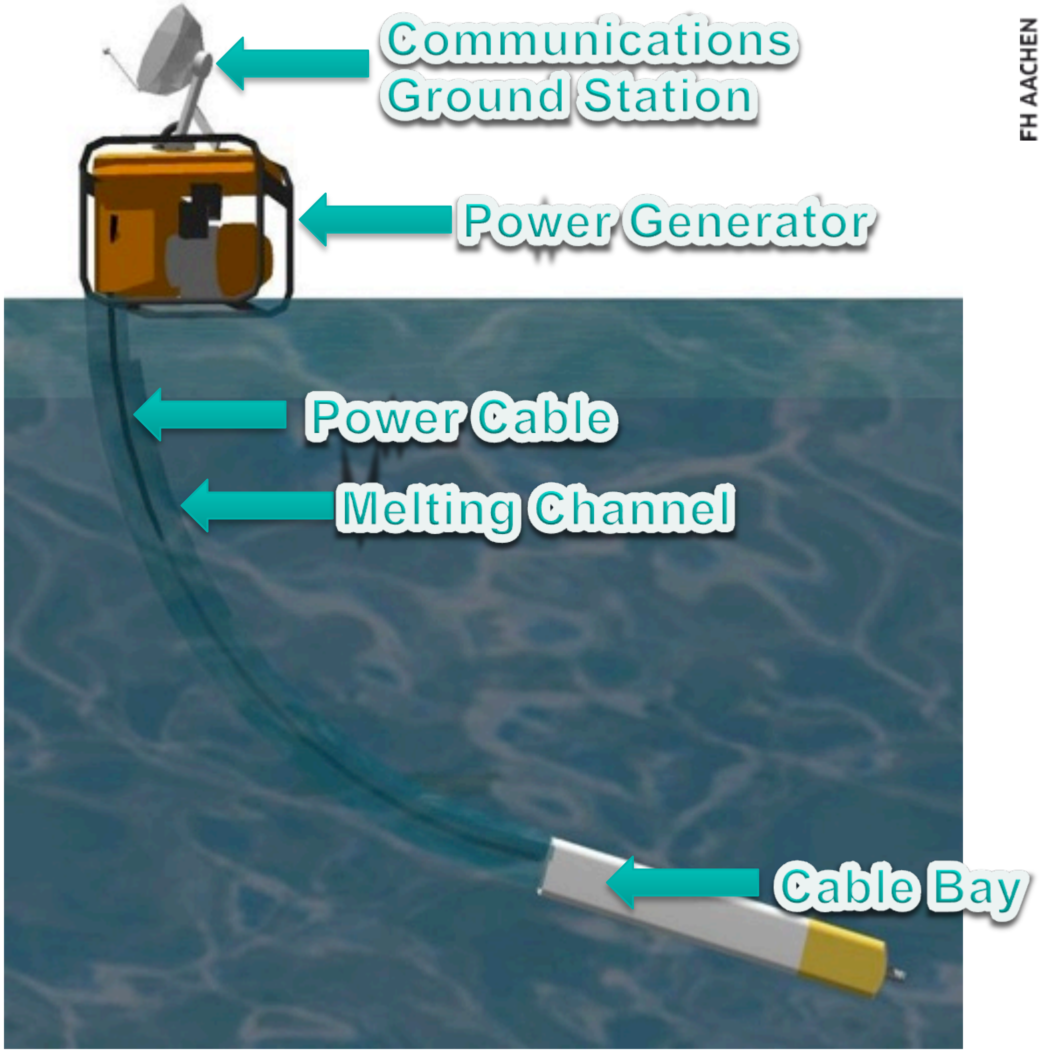
IceMole
Propulsion and Control

- Continuously rotating ice screw at the melting head generates a min. driving force of 1 kN and ingests simultaneously an ice sample
- Length of ice screw is 60 mm (thermally isolated from melting head)
- Heaters are separately controllable:
  - 4 heating zones at the melting head
  - Up to 3.2 kW power at the melting head
  - Cornering ability by differential heating
- Melting velocity ≈ 0.3 m/h
  (suboptimal, can be improved to ≈ 1 m/h)



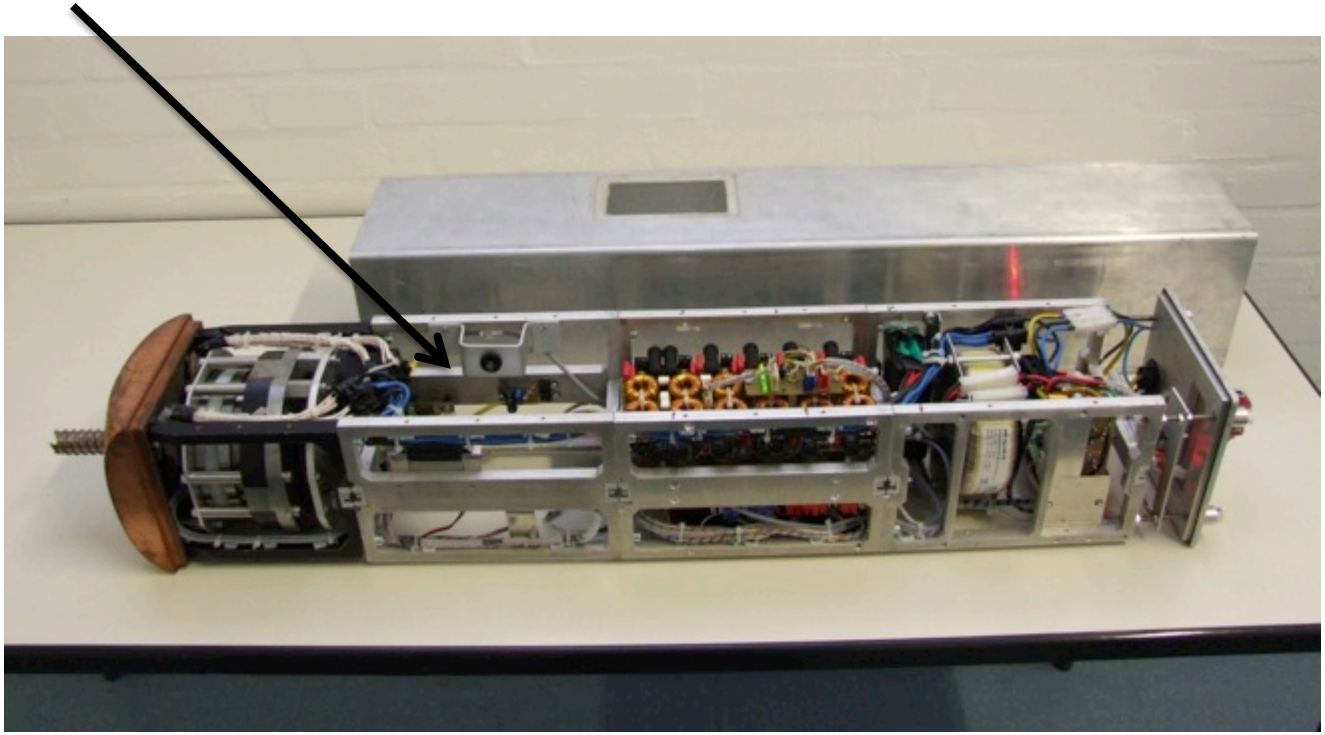
IceMole
Power and Communications

- Power supply with generator
- Power cable is coiled within the IceMole (it freezes behind the probe)
- Powerline-modem trans-mits data between the IceMole and the ground station via the power cable
- Ground station estab-lishes communications with the operations team via satellite/ internet



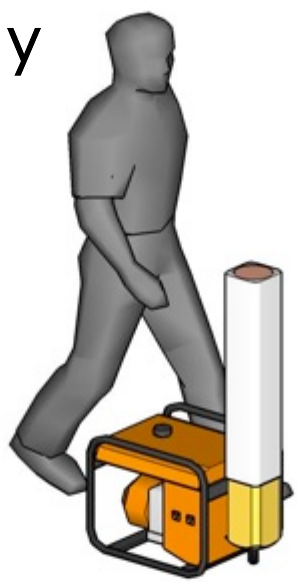
IceMole
Interior View

- Sampling of clean ice core for scientific analysis
- No biological contamination of sampled ice
- Variety of instrumentation options (quadratic instrument bay, 140 × 140 × tbd mm)



IceMole
Features of the IceMole Concept

> Compact
> Mobile
> Robust
> Safe
> Autonomous
> Environmentally friendly (no drilling fluids)



IceMole
Advantages with Respect to Existing Methods

	Drill	Melting Probe	IceMole
Controllability (incl. obstacle avoidance)	↓	↓	↑
Feasibility of space-resolved in-situ profile measurements	→	→	↑
Penetration of “dirt” layers	↑	↓	↑
Recoverability	↑	→	↑
Contamination	↓	↑	↑
Autonomy (incl. weather independency)	↓	↑	↑
Feasibility for Space Applications	↓	↑	↑

IceMole
Terrestrial and Extraterrestrial Mission Scenarios

Extraterrestrial mission szenarios:

- In 20 – 30 years:
  - on Jupiter's moon Europa
  - on Saturn's moon Enceladus
- In 10 – 20 years:
  - on Mars' polar caps

Terrestrial mission scenarios:

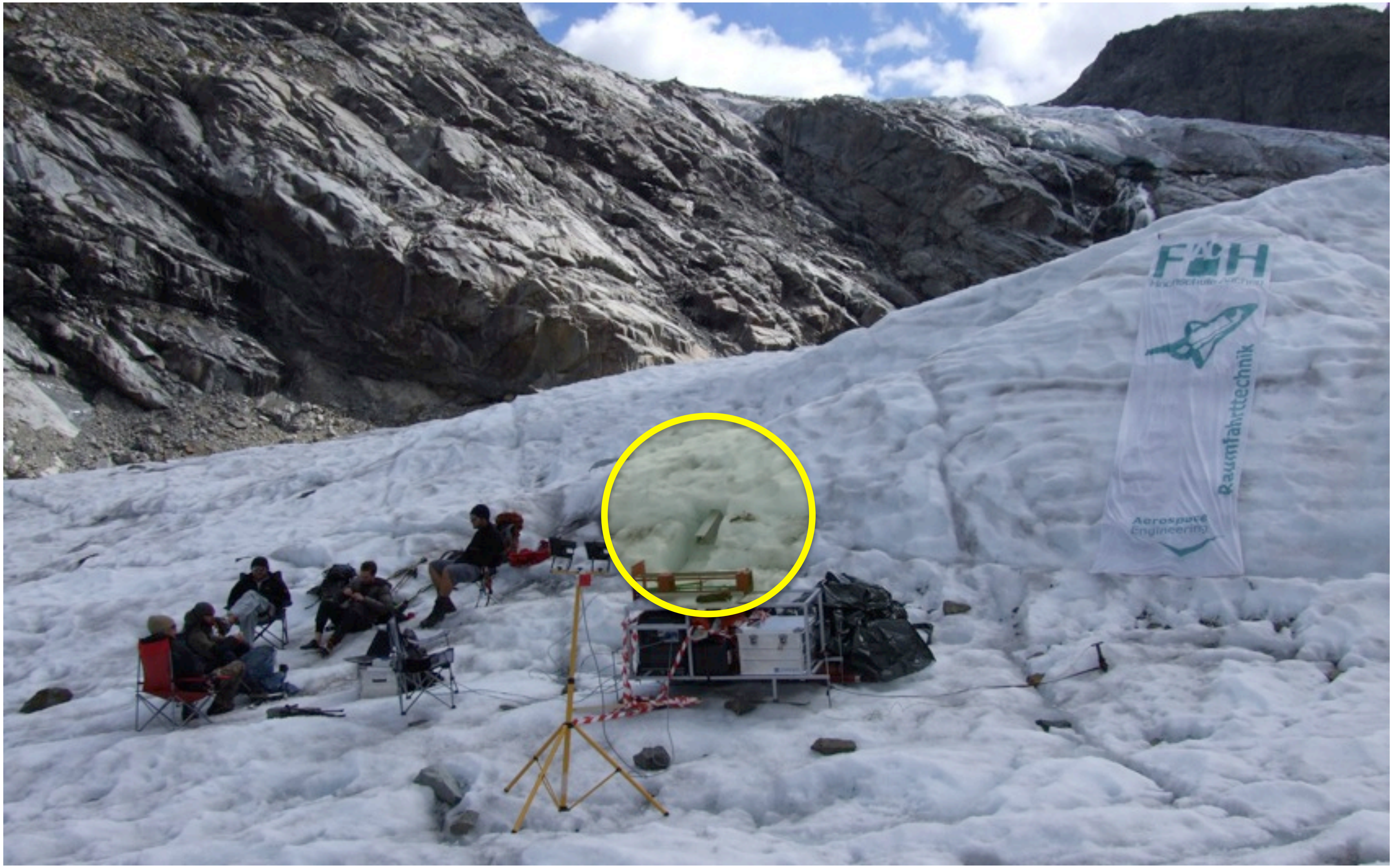
- In 2 – 10 years:
  - in Antarctica's ice (and eventually subglacial lakes)
- Now – 2 years:
  - in glaciers and ice shields

IceMole
Field Experiments on the Morteratsch Glacier (2010)

IceMole
Field Experiments | Material Transport

IceMole
Field Experiments | Field Camp

IceMole
Field Experiments | Field Camp

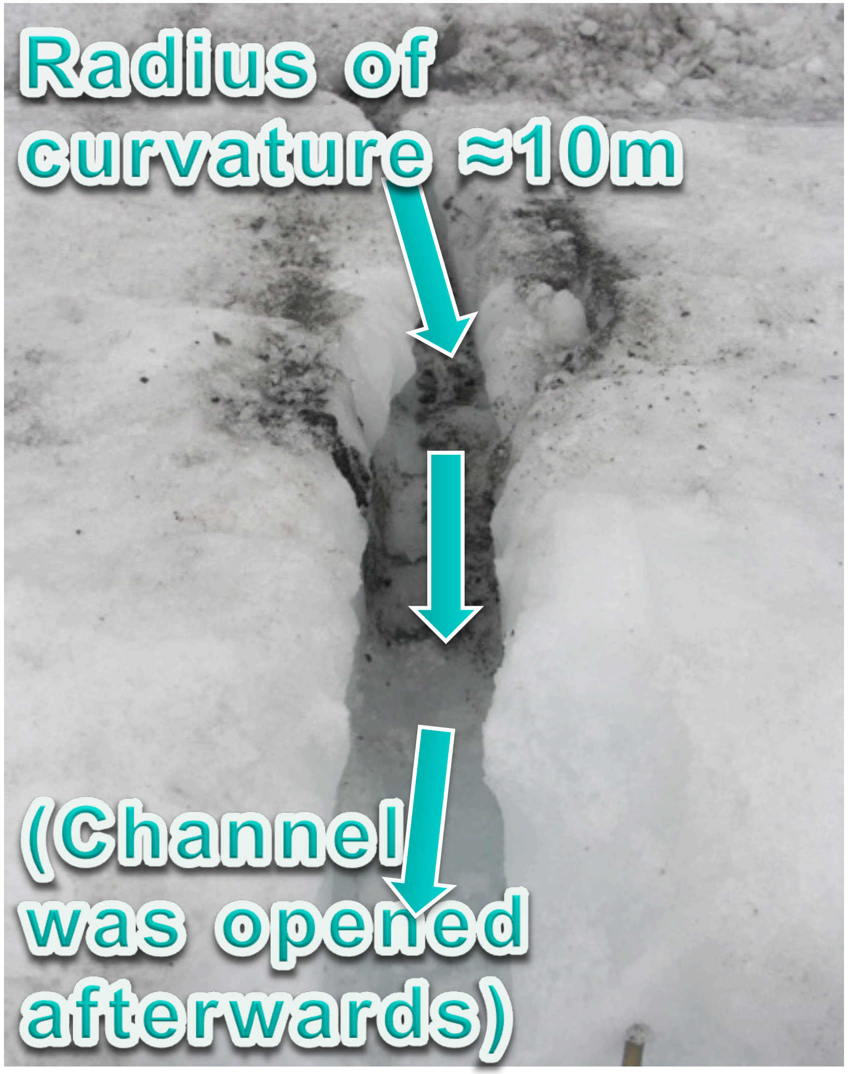


IceMole
Field Experiments | Channel #1

IceMole
Field Experiments | Channel #2

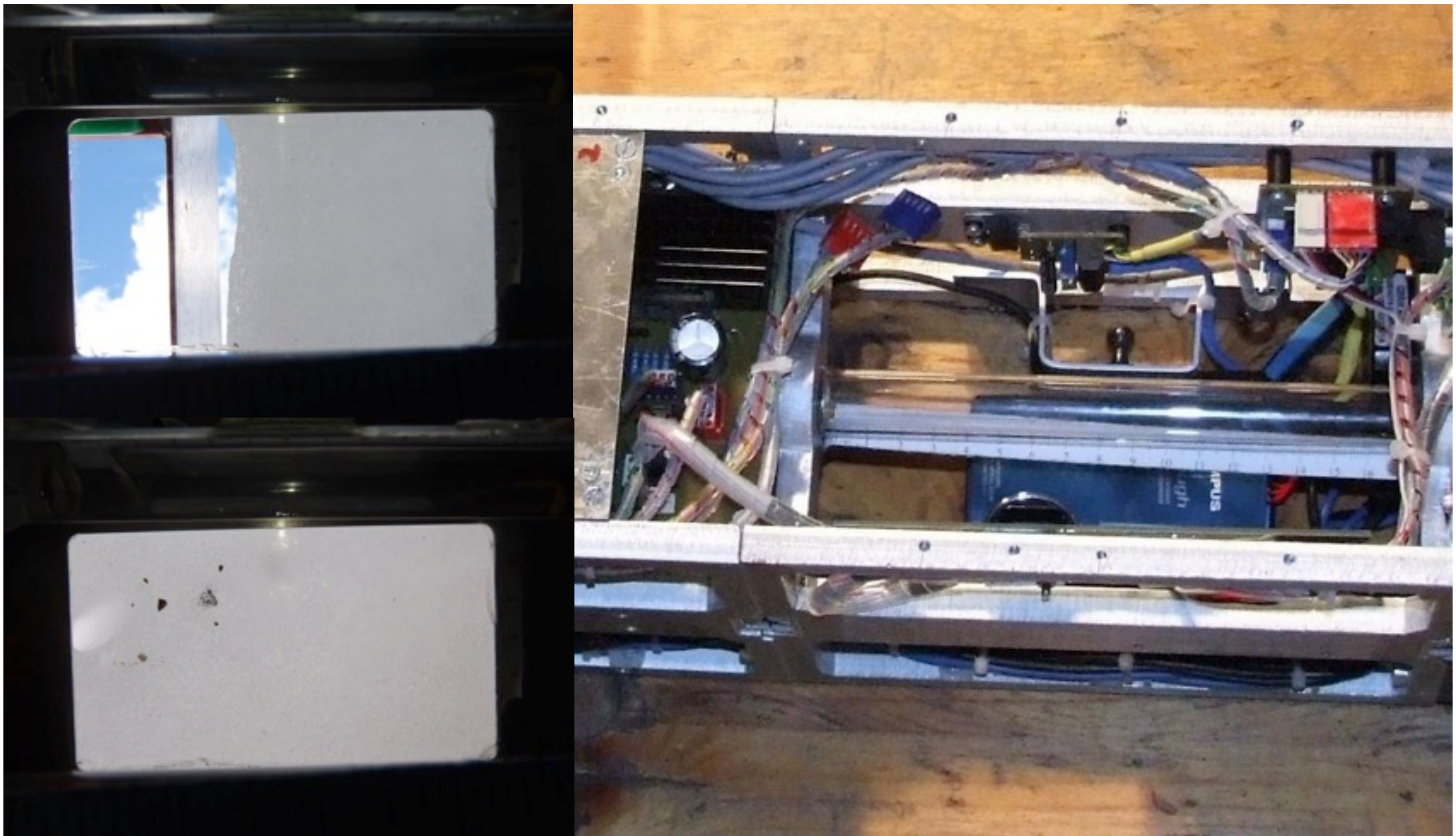
IceMole

Field Experiments | Channel #3



IceMole
Field Experiments | Payload Module

… just a cheap off-the-shelf digital camera



IceMole

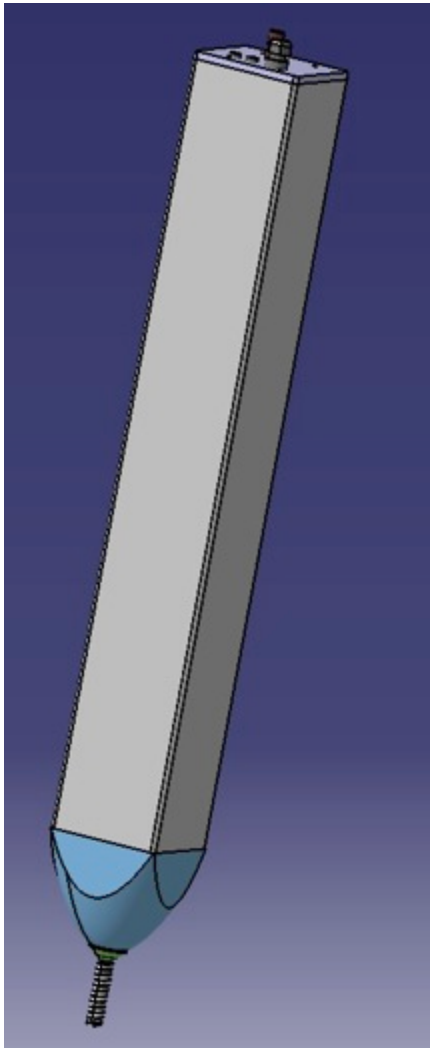
Results and Achievements of the Field Experiment

- > Proven feasibility of the drive concept
- > Curvature radius of about 10 meters
- > Penetration of dirt layers
- > First maneuverable melting probe
- > First probe that can melt upwards, against gravity

IceMole 2

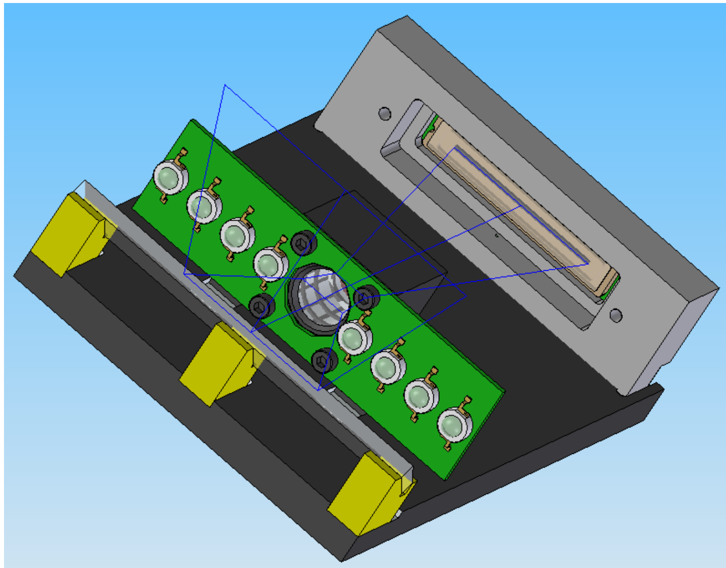
The Next Generation

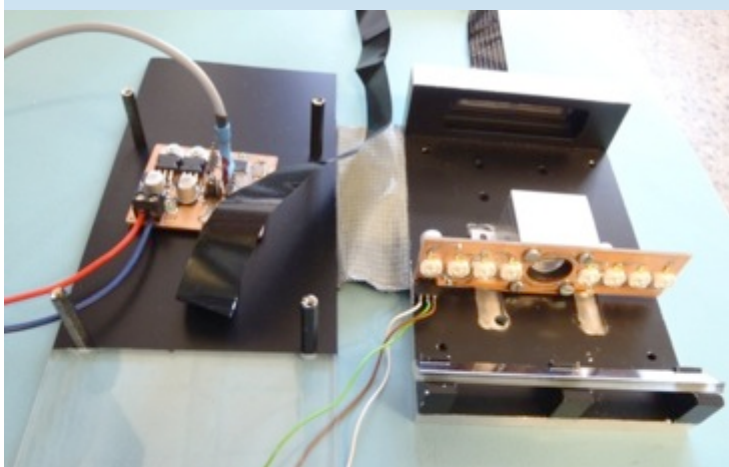
> Heating power:	max. 2.4 kW @ melting head max. 600 W @ wall heaters
> Velocity:	≈ 1 m/h
> Power supply:	24 V DC bus voltage
> Communication:	CAN-bus (internal) Powerline-modem (external)
> Payload module:	Fluorescence biosensor
> Pressure: resistance	up to 5 bar

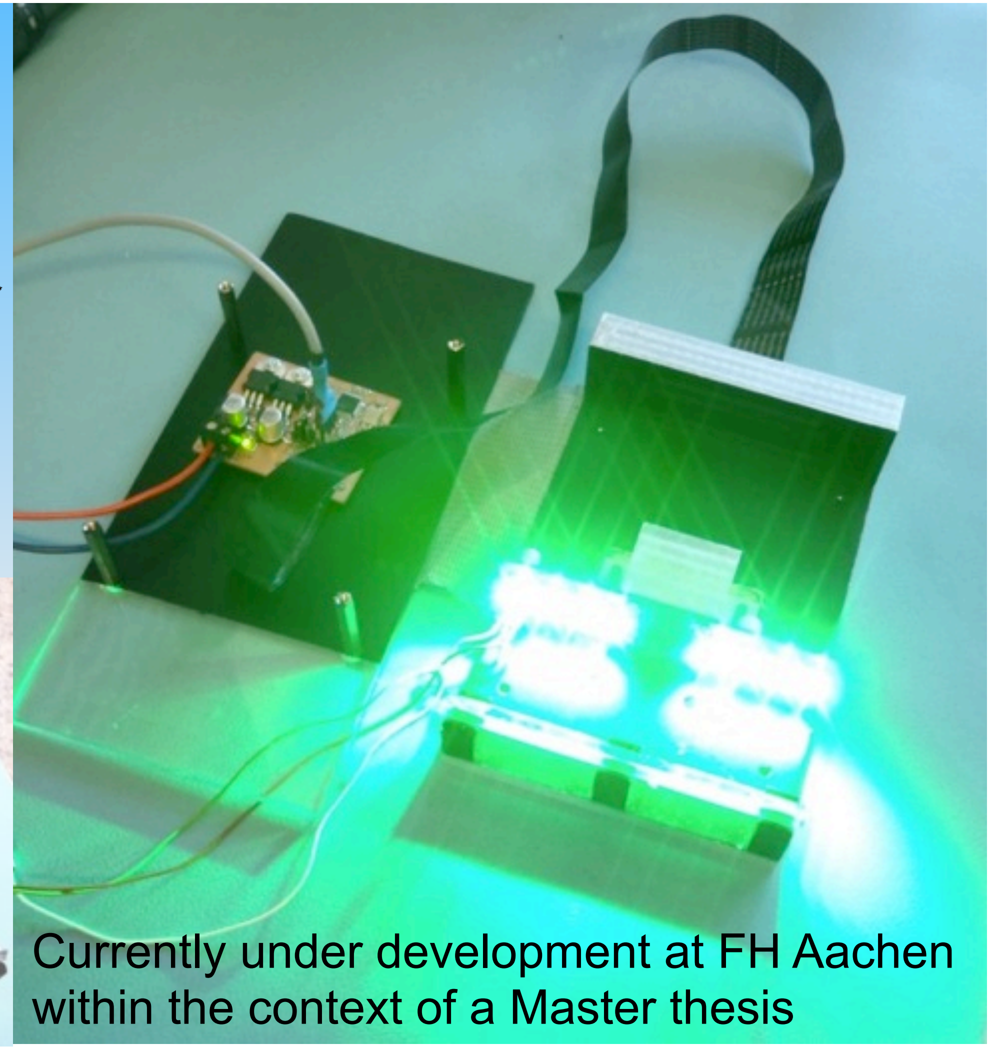


IceMole 2

Payload 2012 | “Simple” Fluorescence Biosensor

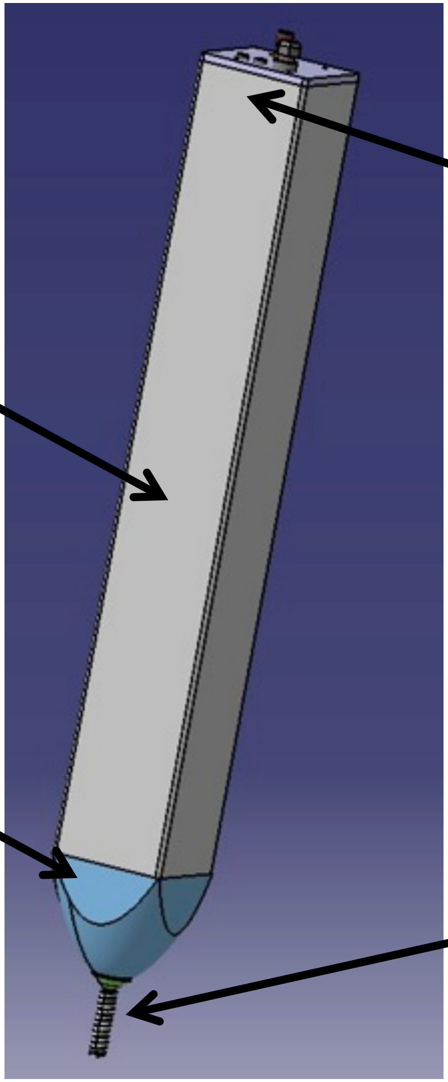






Currently under development at FH Aachen within the context of a Master thesis

IceMole 2
External Structure



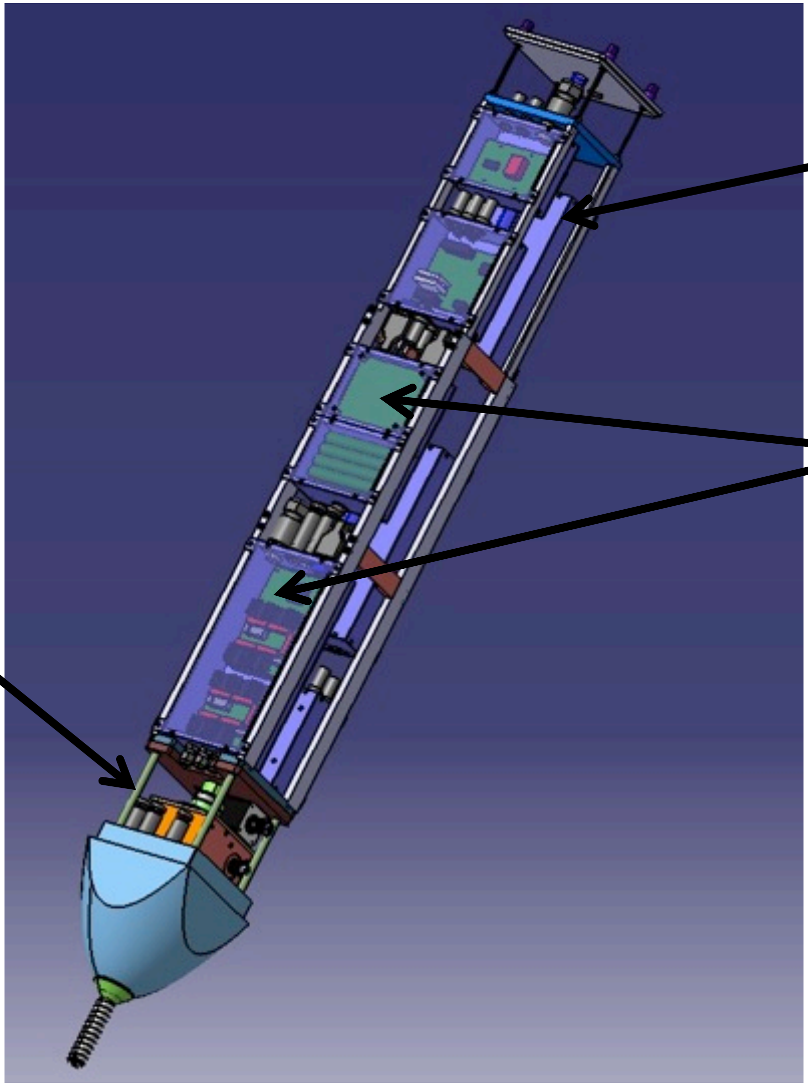
Power supply and communications

Aluminum tube

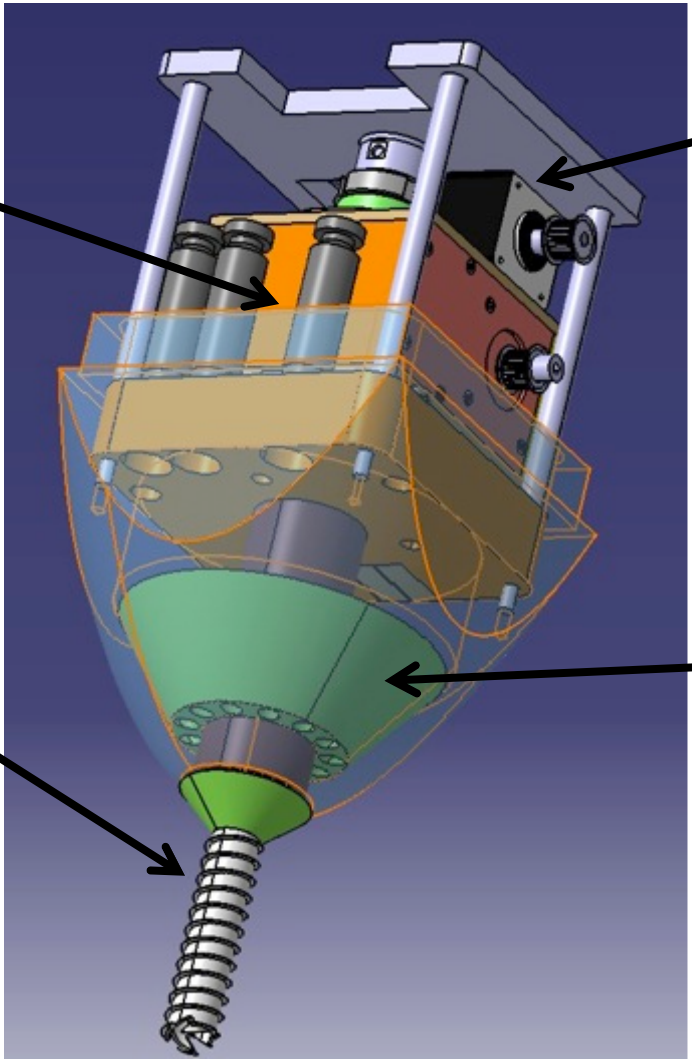
Re-designed melting head

Ice screw

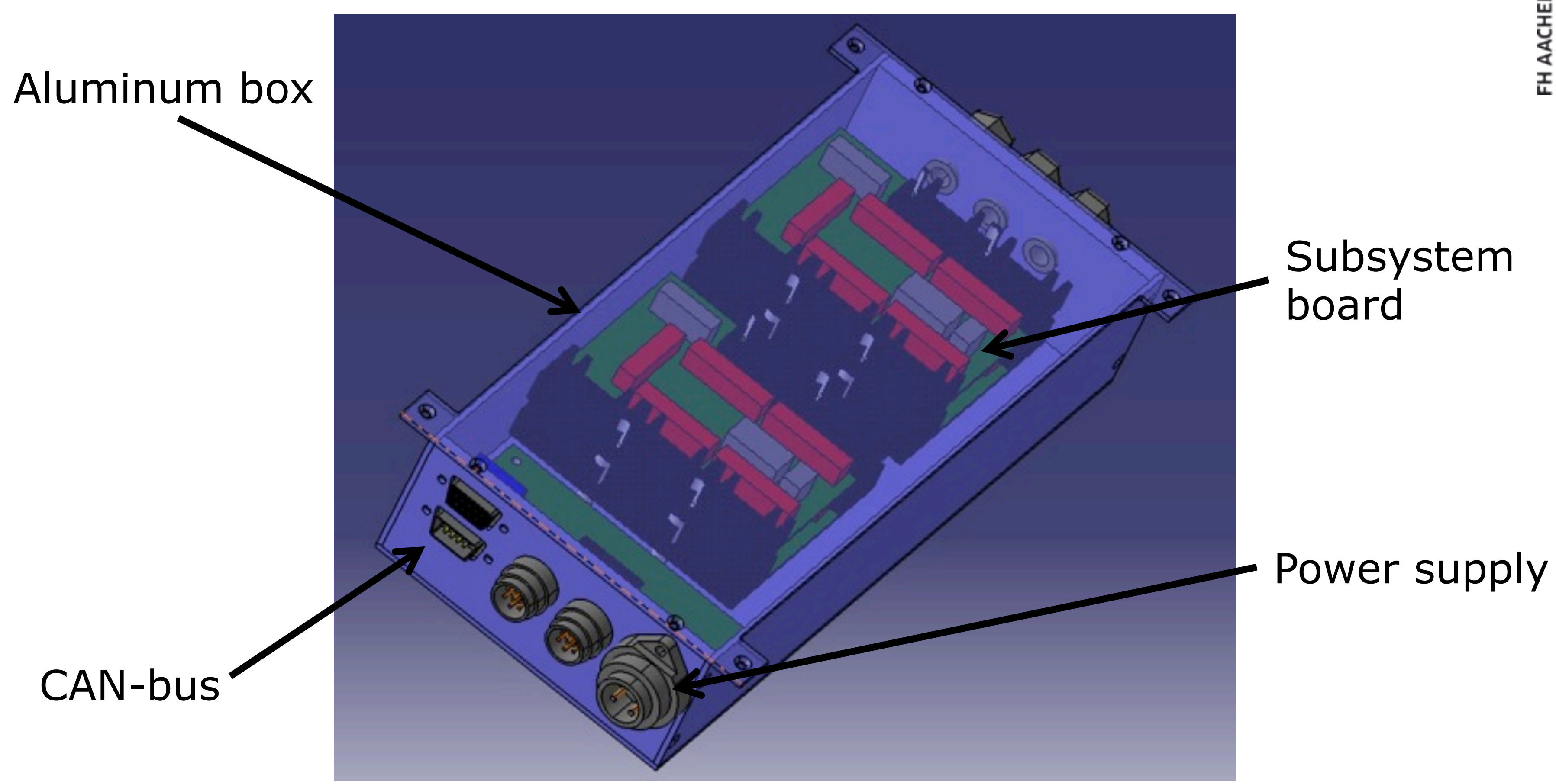
IceMole 2
Internal Structure



IceMole 2
Re-Designed Melting Head

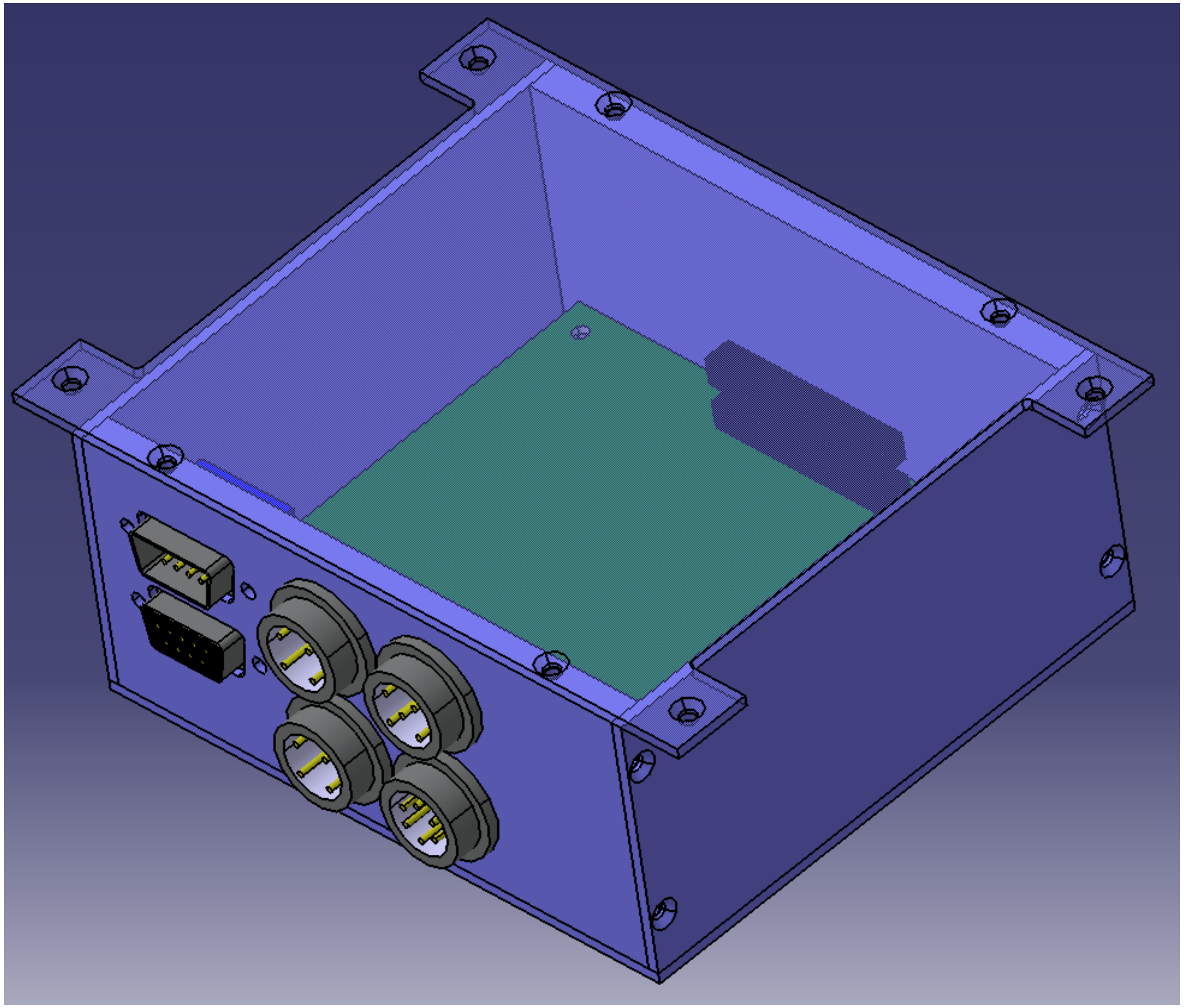


IceMole 2
Electronic Boxes



IceMole 2
Payload Requirements

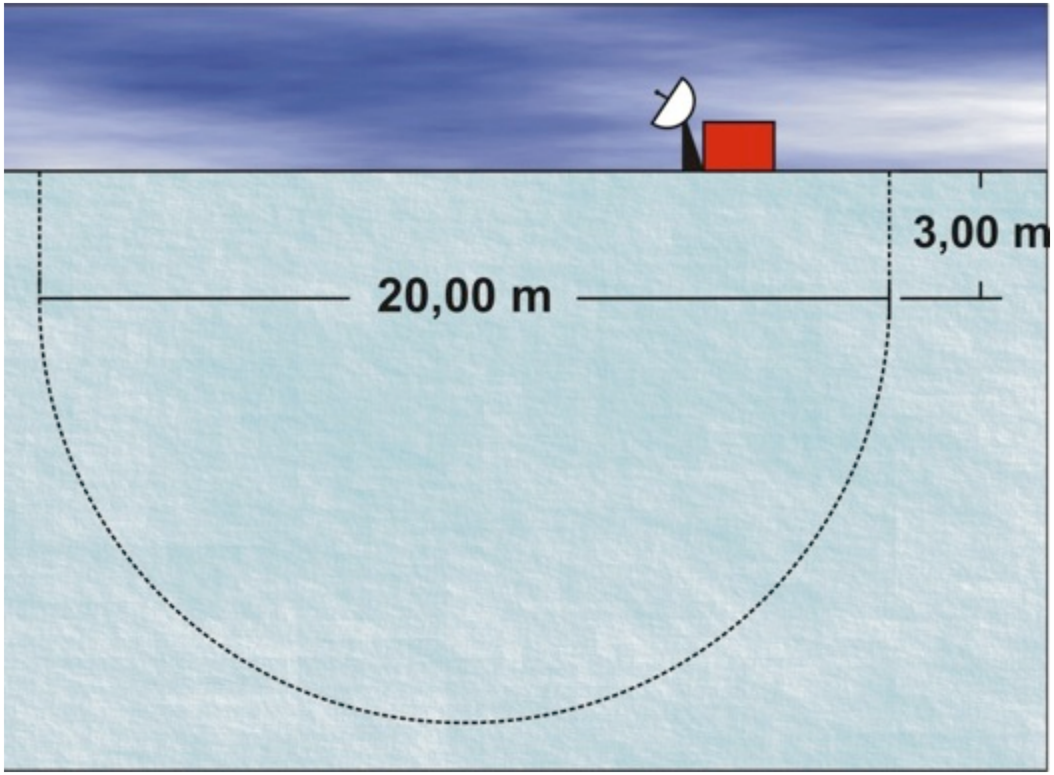
110 x 50 x tbd mm
24 V DC
CAN-Bus



IceMole 2
Mission Objectives for Field Experiments in 2012

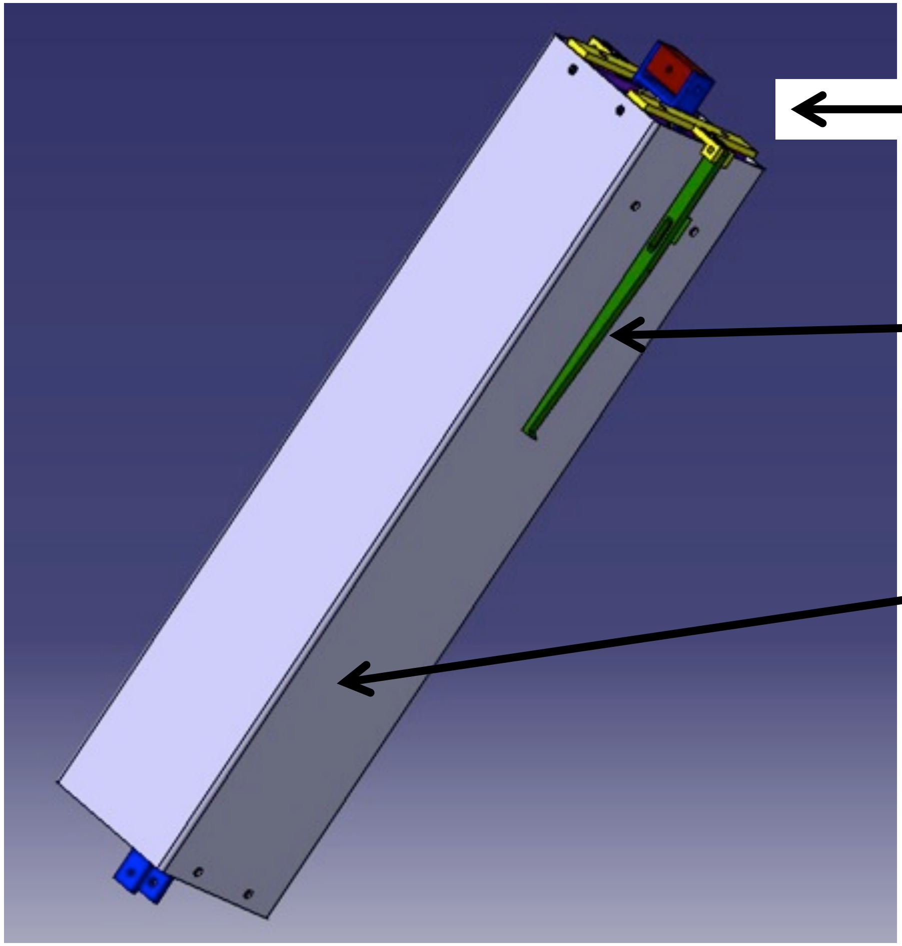
1) Demonstrate the recoverability of IceMole and payloads
2) Dig a horizontal "U"
3) Dig a vertical "U"

> Distance:
  ≈ 40m
> Duration:
  50 – 150 hours



IceMole 2
Tether Container

2012 field experiments: 5 containers with 10 m of tether each



Undocking mechanism

Clamp jaw

Tether bay

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IceMole 2
Future Technical Challenges

> **Power:** transmission of several kW of power over large distances / depths

> **Communications:** communications over the power cable

> **Navigation:** 3D navigation under the ice

> **Control:** autonomous and robust control

> **Drive:** optimization of ice screw and drive mechanism

> **Thermal Control:** optimization of cornering ability, thermal computer simulation

Source: http://www.classicalarchives.com/prs/astro/Antarctica/0605-Ice_Cube_drilling.jpg

ICE MOLE
Subsurface Icecraft

IceMoliνo – Plans for Future IceCube-Related Research

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27. April 2011

Bernd Dachwald[1,*], Christopher Wiebusch[2], Changsheng Xu[1], Marco Feldmann[1], Clemens Espe[1], Gero Francke[1], Karim Laihem[2], Engelbert Plescher[1] and the IceMole Team[1]

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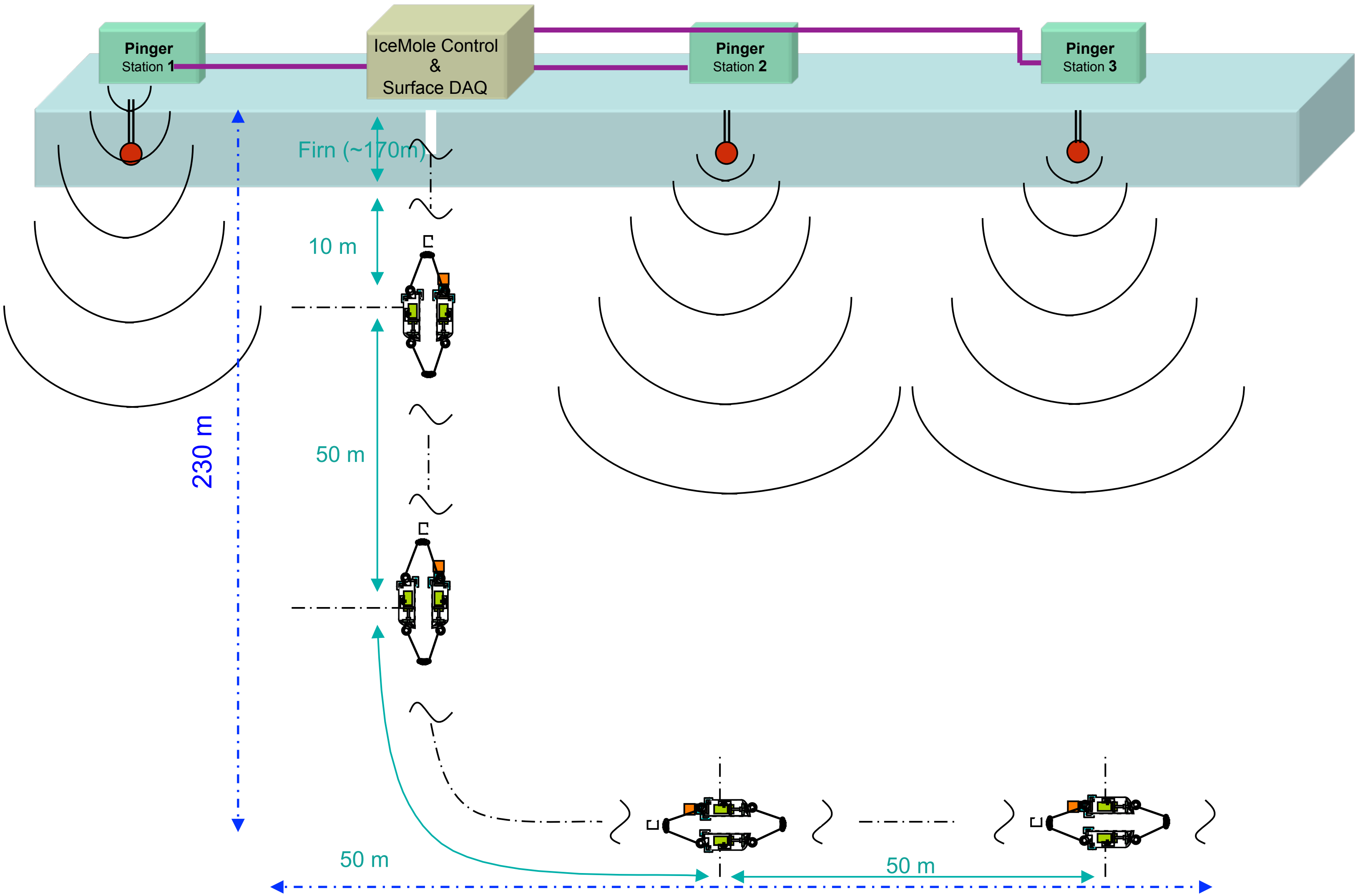
IceMoliνo
Mission Objectives

1. Demonstrate capability to drill and deploy scientific equipment in deep ice

2. Use acoustic equipment – not for neutrino detection – but for verification of navigation by acoustic triangulation

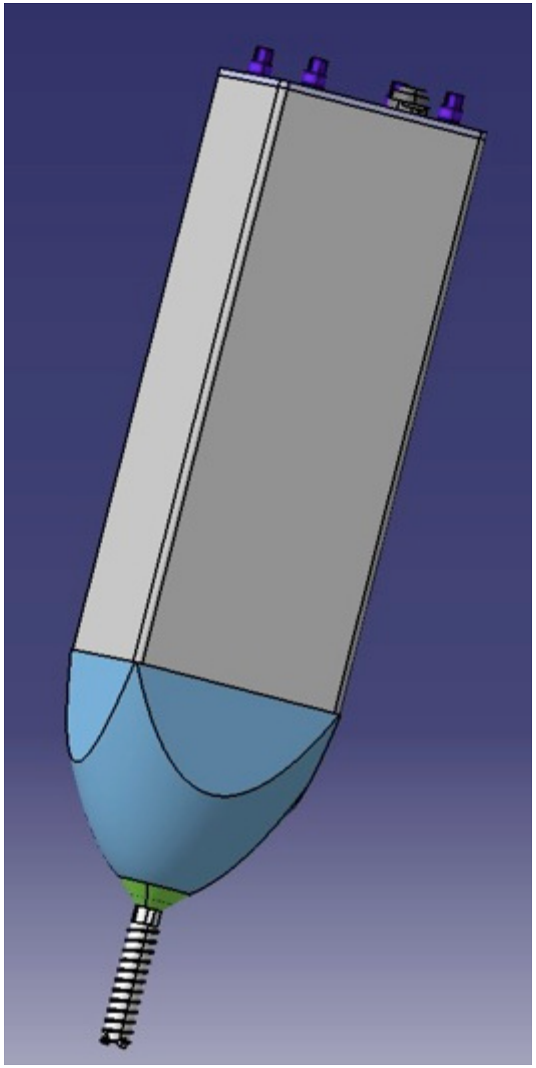
3. Measure absolute noise level as critical parameter for acoustic neutrino detection

IceMoliνo
Mission Setup



IceMoliνo
Probe Design and Mission Requirements

- Sensor string with 4 accoustic sensors
- 230 m vertical path and then >75 m horizontal path
- Positioning accuracy ± 10 m
- IceMole cross section 150 x 150 mm
- Length ≈ 600 mm
- No ice core
- Incompressible medium inside the probe (e.g., silicon oil)
- Pressure resistance ≈ 90 bar



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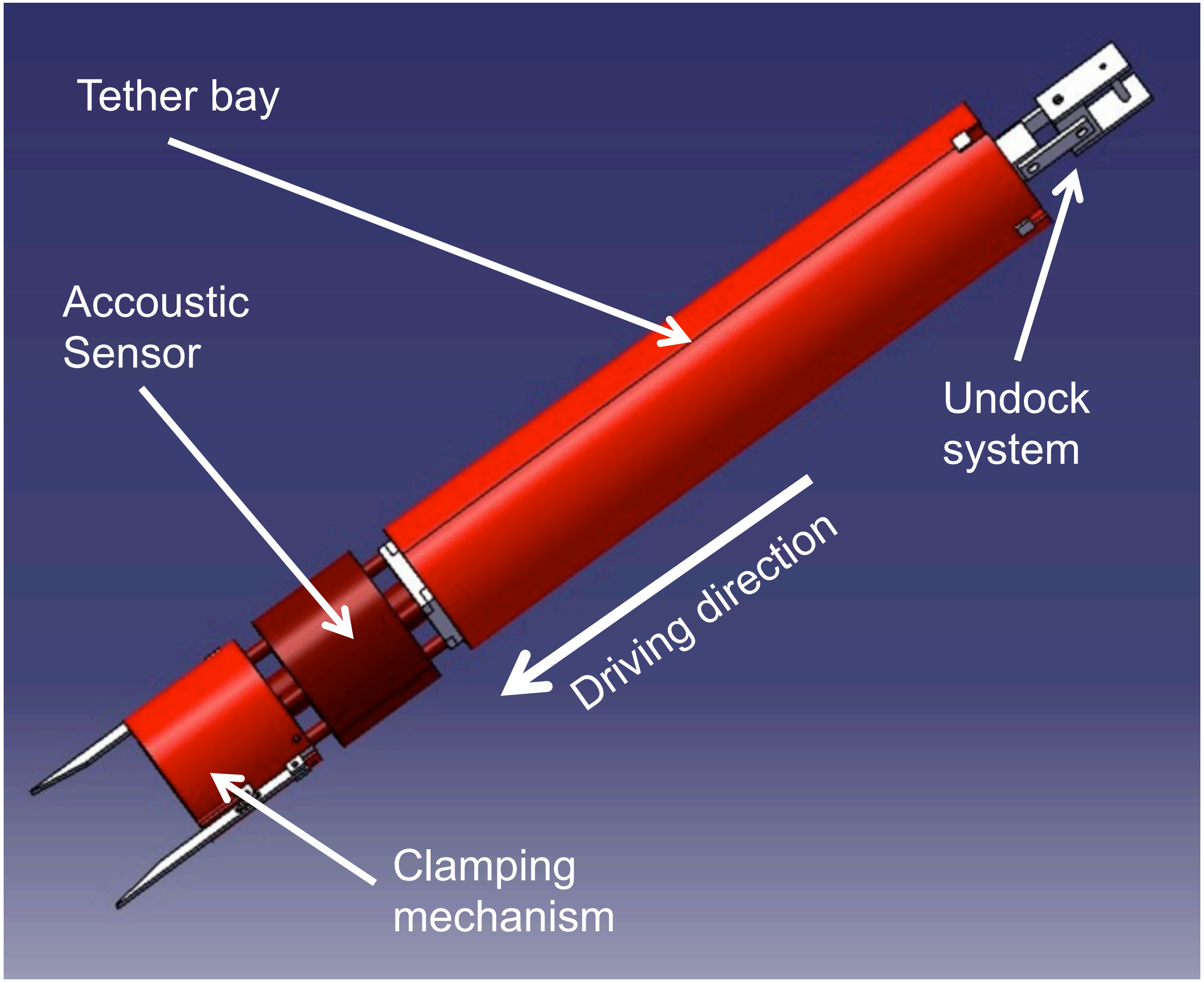
IceMolivo

Tether Container with Integrated Accoustic Sensor



Thank you for your attention!

Questions?

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