# Enceladus Explorer Project

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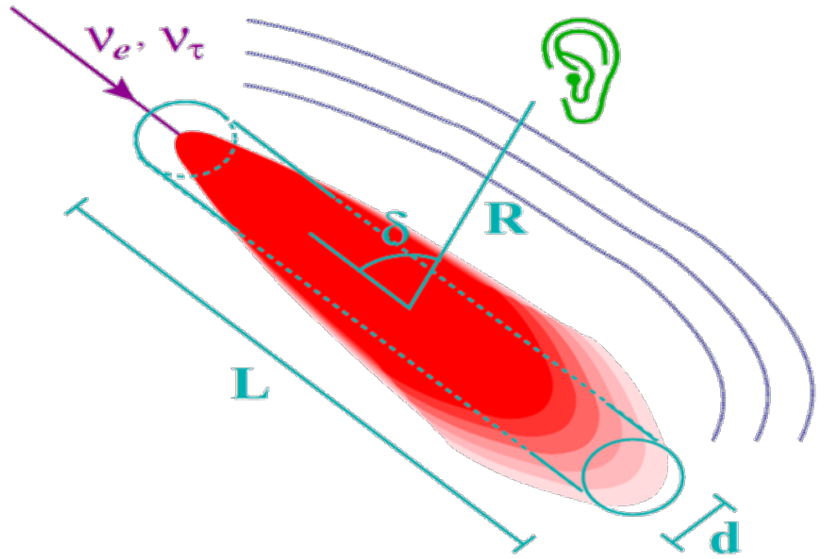
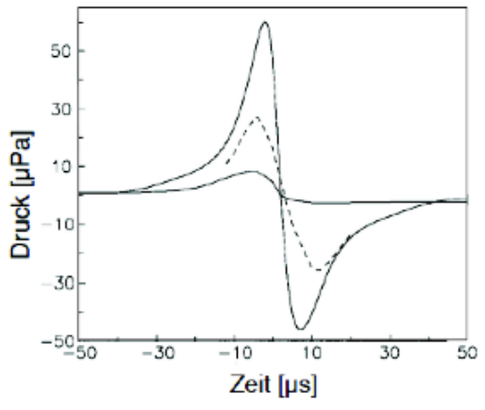
# Outline

- Acoustic neutrino detection
- Enceladus Explorer Project
- IceMole
- Acoustic positioning system
- Acoustic reconnaissance system
- Full system tests on the Morteratsch Glacier
- Summary & Outlook

# Acoustic neutrino detection

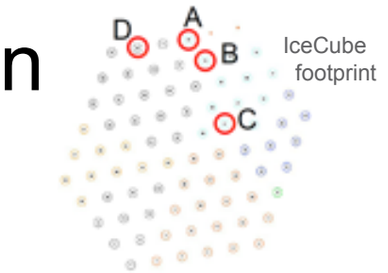
- Detection of ultra high energetic neutrinos, e.g. GZK (E ~ $10^{20}$eV), through thermo acoustic effect in matter
- Weak interaction
  - Hadronic cascade
  - Local heating (~nK)
  - Local thermal expansion
  - Acoustic shock wave
  - Bipolar pressure pulse



# SPATS
## South Pole Acoustic Test Setup

- Feasibility study for acoustic neutrino detection
- 4 strings with each 7 modules
  - Distances 125m to 543m
  - Depth -80m to -500m
- Deployed on the top of the IceCube detector (2006-2008) (Holes 78, 72, 47, 76)



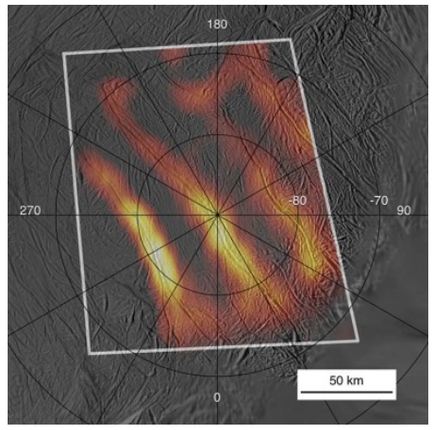




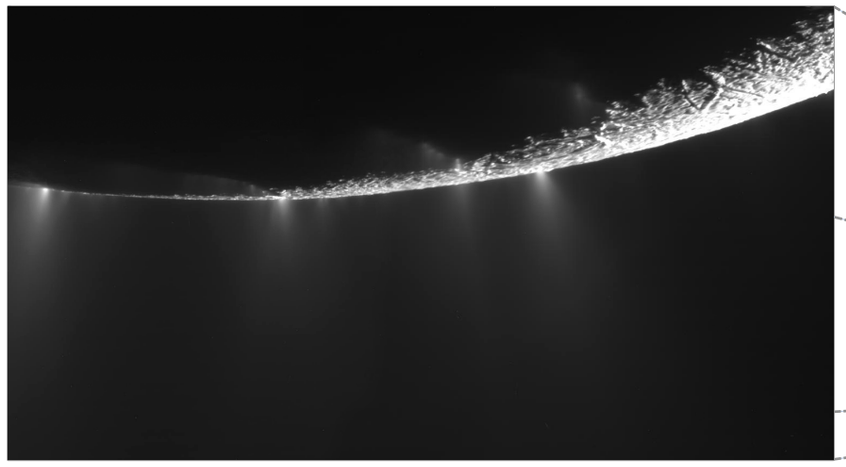
- Connection to the Enceladus Explorer Project (EnEx):
  - Development of acoustic sensors & data systems
  - Determination of the position of acoustic sources in ice

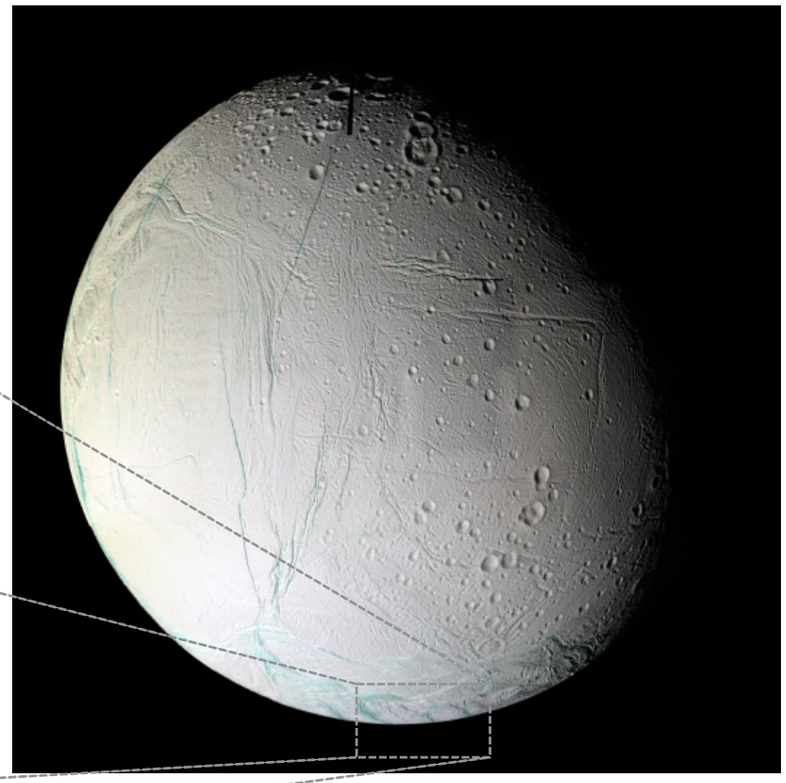
# Enceladus

- Enceladus is the 14th Saturn moon
  - Diameter 500km
  - Completely covered with an ice crust
- Cassini observations
  - Tiger stripes (south pole)
  - Cyrovolcanoes eject geysir-like jets of water vapor, ice, salt and organic molecules
  - Gravity measurements indicate a large underground ocean of liquid water




**Is there life on the Enceladus?**

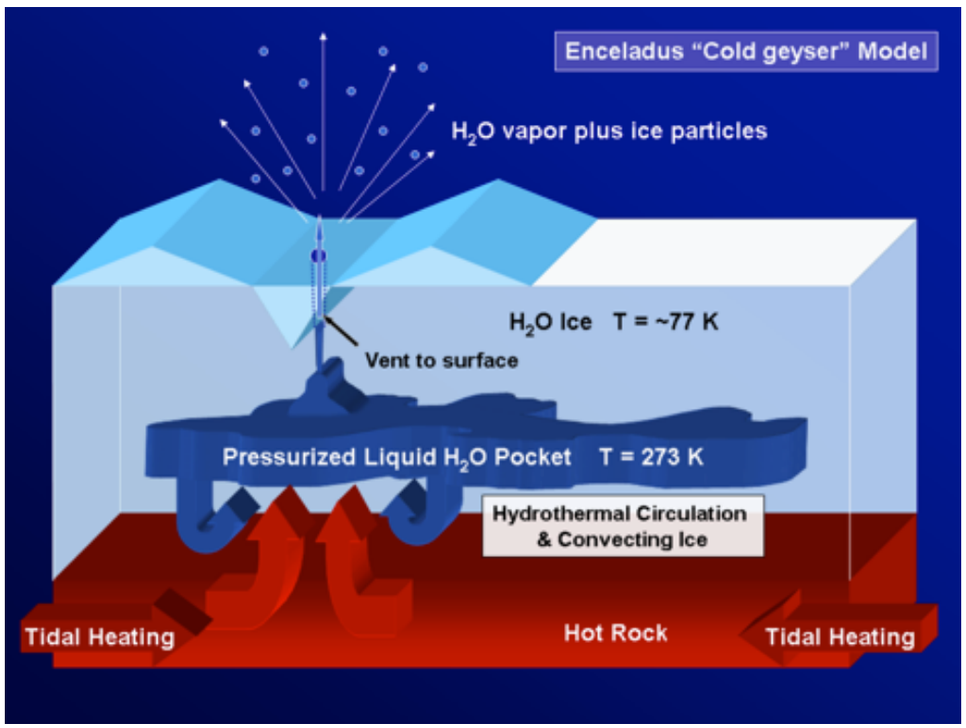




(Image credit: NASA/JPL/SSI)

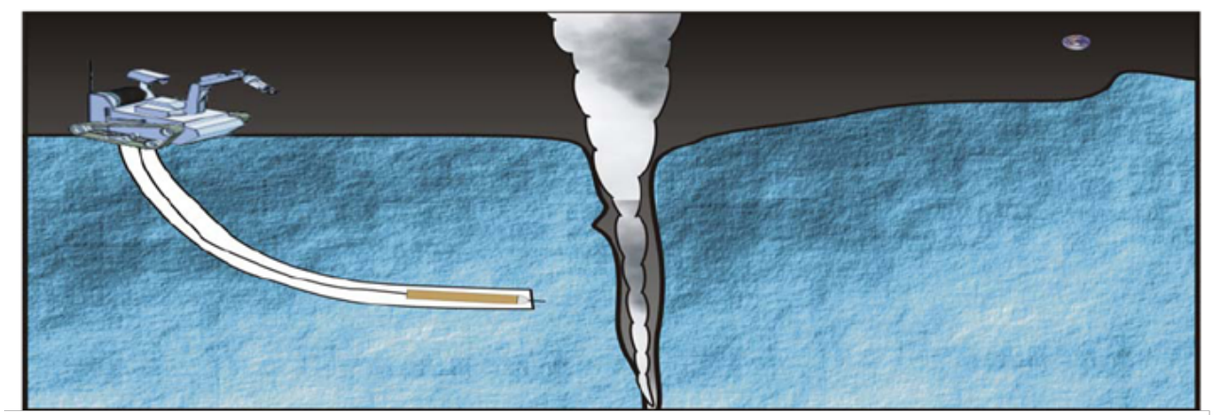
# Idea Enceladus Explorer

- „Cold geysir“ model
- Tidal heating of core
- Pressurized liquid water pocket
- Vents to the surface




- Idea: Tip the vent with an ice craft
  - Development of technology for specialized ice craft
  - Test the ice craft in terrestrial test scenarios

➡ Enceladus Explorer Project

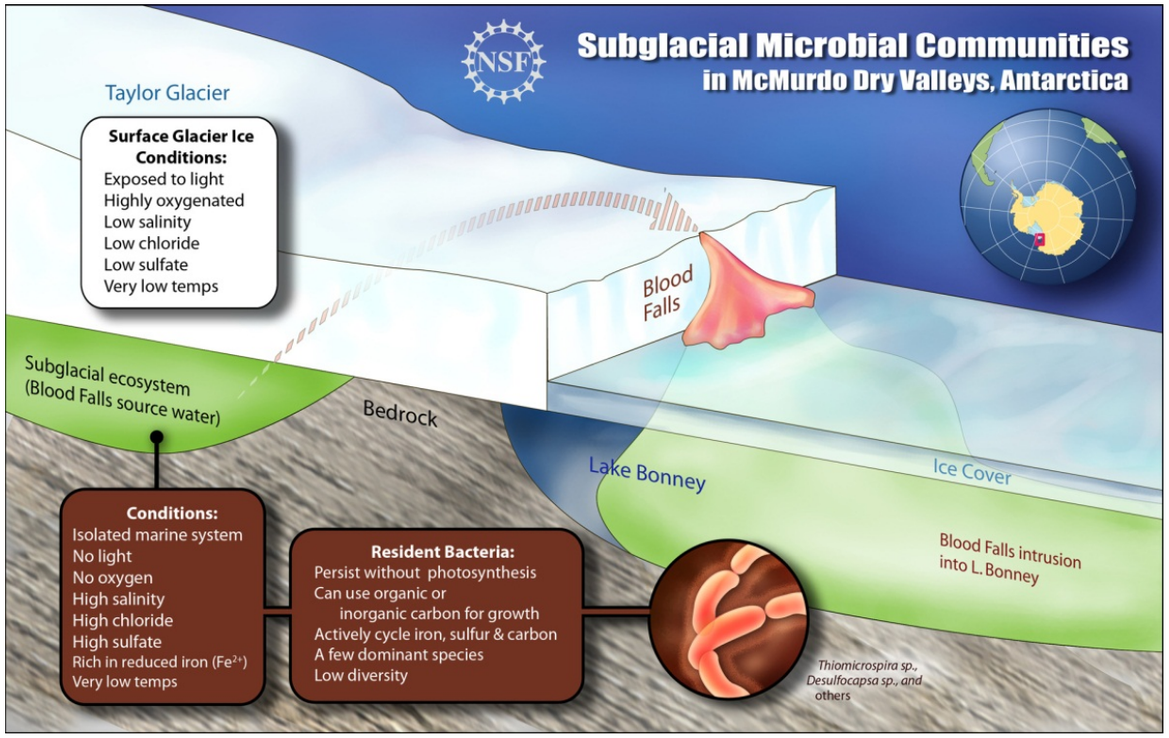


# Terrestrial test scenario
## Blood Falls

- Taylor Glacier, McMurdo Valley, Antarctica, December 2014
- Sub glacial lake beneath 400m ice layer
  - Unknown ecosystem
  - Isolated since 1-2 Mio. Years

- Sporadic emergence of “red” brine from fissure at glacier tongue
- Ferrous irons + atmospheric oxygen: “Blood Falls”

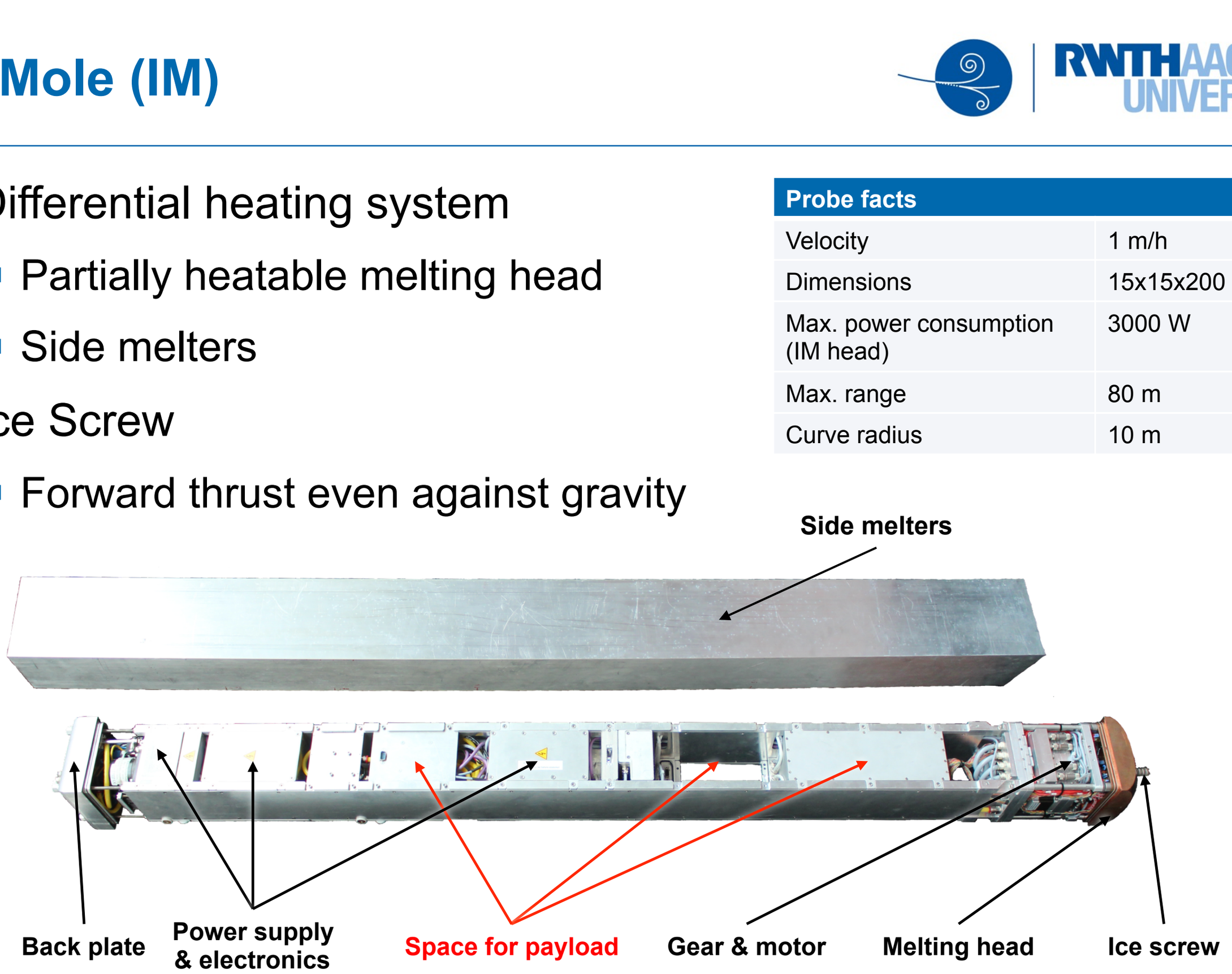
➡ Sampling of the brine filled fissure



# IceMole (IM)

- Differential heating system
  - Partially heatable melting head
  - Side melters
- Ice Screw
  - Forward thrust even against gravity

| Probe facts | |
|---|---|
| Velocity | 1 m/h |
| Dimensions | 15x15x200 $cm^3$ |
| Max. power consumption (IM head) | 3000 W |
| Max. range | 80 m |
| Curve radius | 10 m |

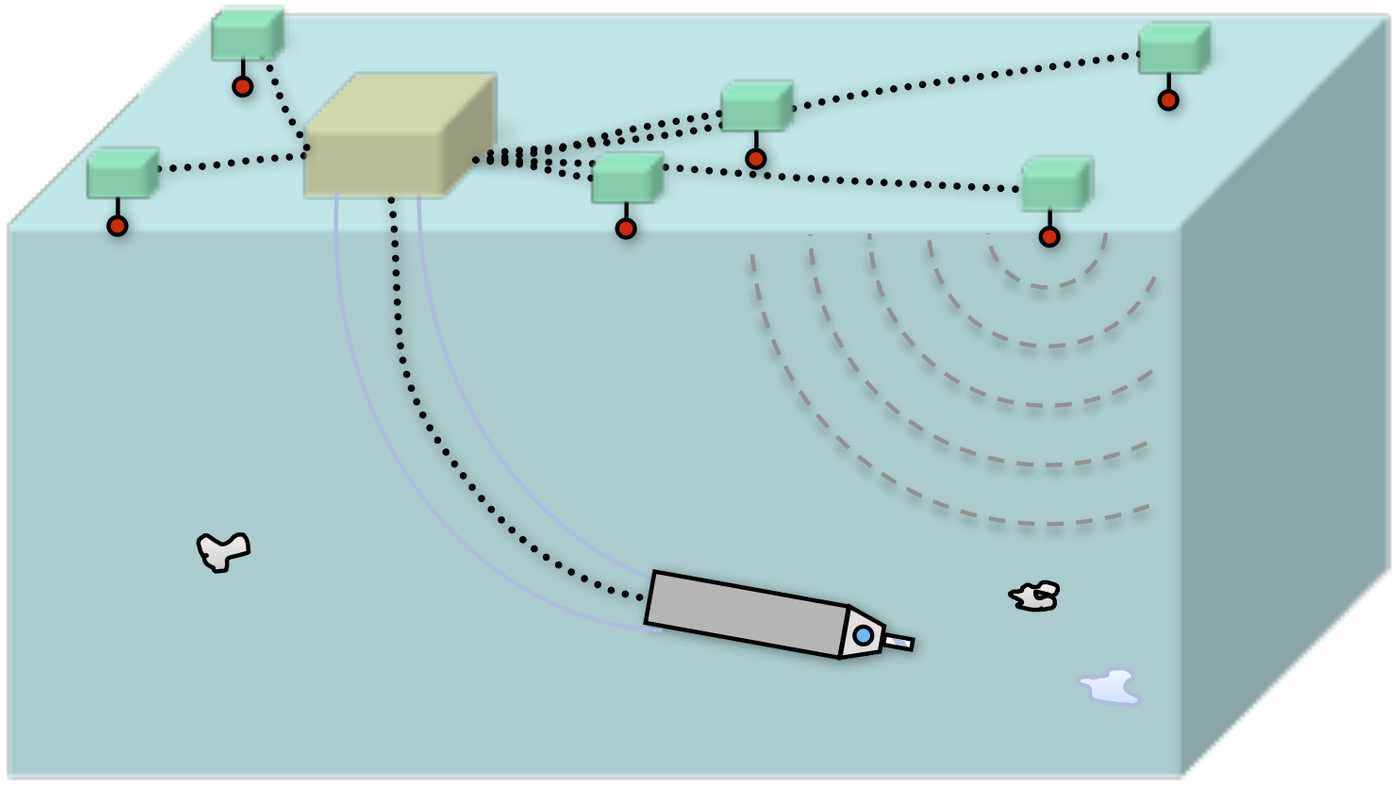


# Enceladus Explorer
## Subsystems

- Ice craft: Specialized IceMole
- Surface station
  - 2 PCs (control & navigation)
  - Power generators
- Navigation
  - Inertial measurement unit, magnetometers
  - Acoustic positioning system
  - Acoustic reconnaissance system
- Decontamination
- Extraction of sample brine
  - Sampling system with sample bags, pumping to surface

# Acoustic positioning system
## Idea

- Goal: Determination of absolute probe position with accuracy of 1 m after 100 m trajectory
- Idea: Determination of the position via trilateration



# Acoustic positioning system
## System Overview

Operator

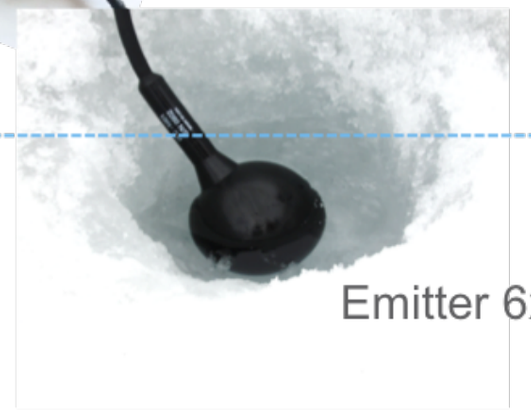
Navigation
Database
Processing

Central control unit

Front end electronics 6x

on surface

in-ice



Emitter 6x

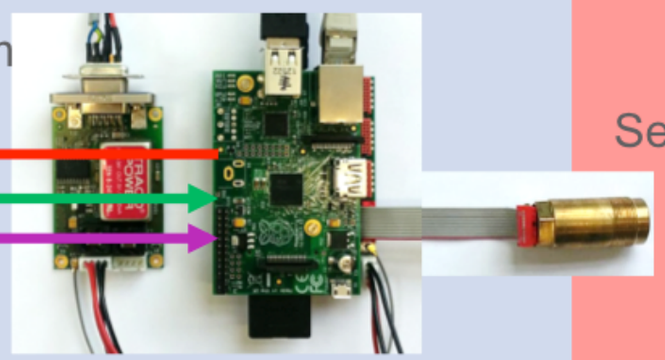
Emit command

Acquisition command

Synchronization

Raw data &
propagation times

Acoustic data acquisition system



Sensors 4x

IceMole

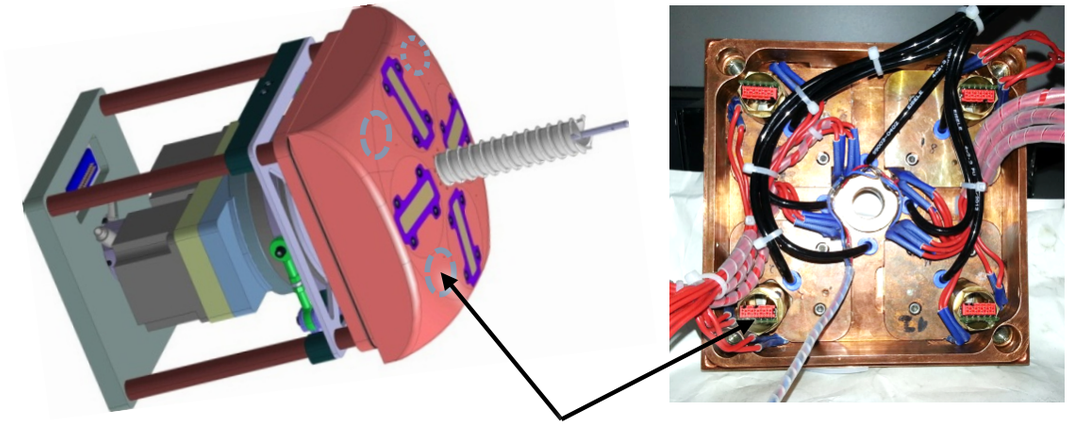
# Acoustic positioning system
## Design

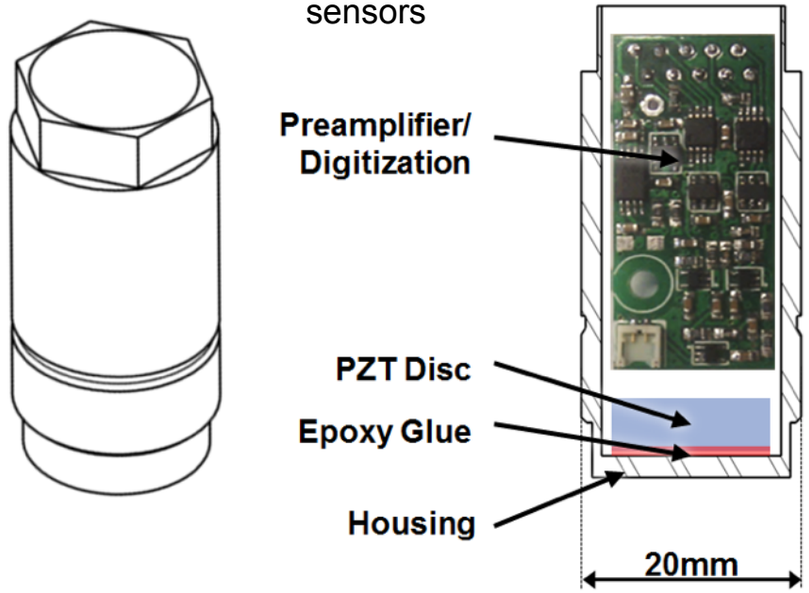
- Surface components
  - 6 emitters (18kHz) distributed in the upper ice layers of the glacier
  - Signal generation in central control unit
- Components within IM probe
  - 4 sensors integrated in IM head
  - Data acquisition within IM (FPGA & embedded PC)
- Connection
  - Synchronization signal via dedicated cable
  - Communication via UDP, TCP/IP

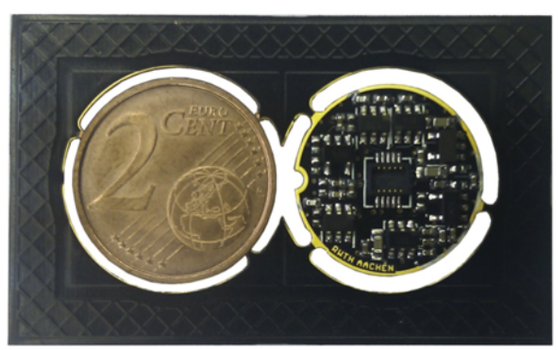
# Acoustic positioning system
## Receivers

- 4 sensors integrated in IM head
- PZT disks
  (diameter 16mm, thickness 3mm)
- Metal housing for easy mount
- Disks coupled to sensor electronics
  (2 stage preamplifier and digitalization)
- Good acoustic coupling between PZT and IM head as well as IM head and ice needed

➡ Optimized for precise determination of the arrival time

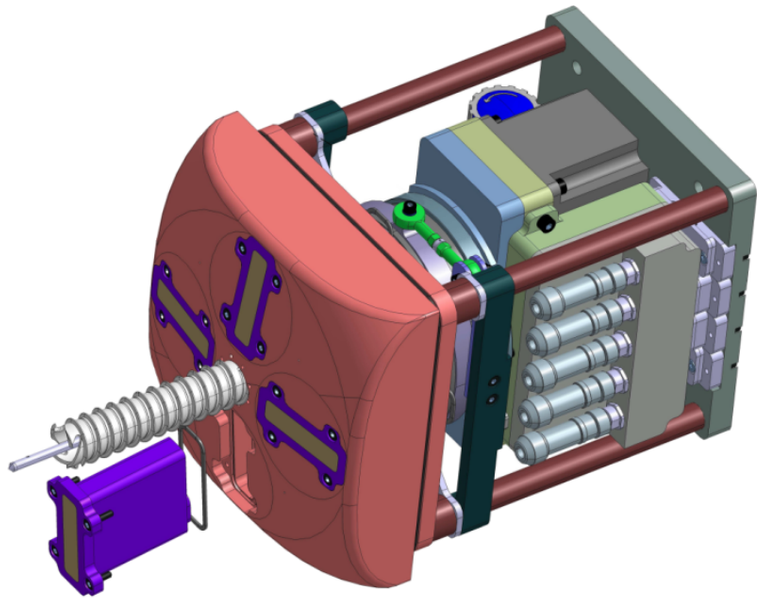


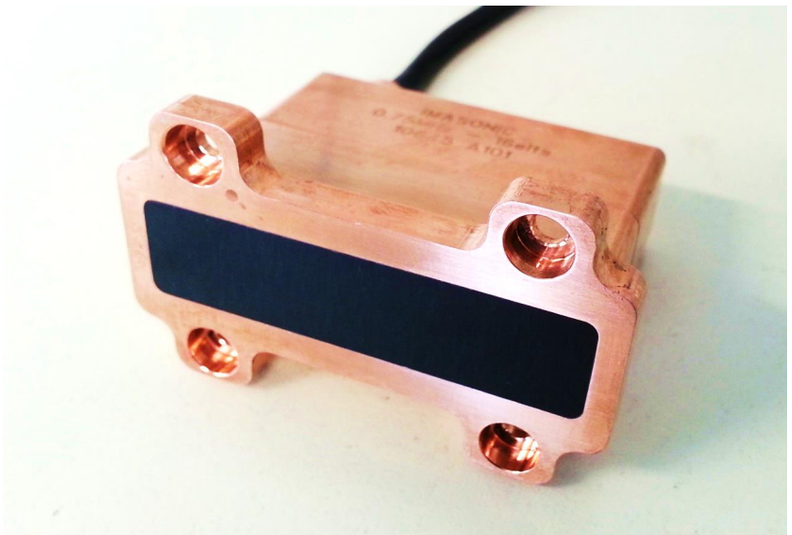



# Acoustic reconnaissance system

- Goal: Identification of obstacles as well as point of interest in front of the probe
- Idea: Use similar technique to medical ultrasonography



- Components within IM probe
  - 4 piezo arrays (16 elements, 780 kHz) as emitters and receivers, situated crosswise around the ice screw
  - Data acquisition within IM (FPGA & embedded PC)
- Connection
  - Communication via UDP, TCP/IP



# Overview Field tests

- **FT0: Morteratsch, Switzerland, Aug 2012**
  Test of concept for acoustic position ✓
- **FT1: Morteratsch, May/June 2013**
  Specialized IceMole, ground station, acoustic positioning system, IMU & magnetometer ✓
- **FT2: Canada Glacier, Antarctica, Nov 2013**
  Acoustic reconnaissance system, decontamination, sample extraction ✓
- **FT2.5: Morteratsch, June 2014**
  Optimization of full system, run control ✓
- **FT-3: Blood Falls, Antarctica, Dec 2014**
  Sampling of the brine filled fissure

# Field test June 2014
## Morteratsch Glacier in Switzerland

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# Field test June 2014
## Morteratsch Glacier in Switzerland

# Summary & Outlook

- Acoustic neutrino detection via thermo acoustic effect
- Search for life on Enceladus or at Blood Falls
- System Overview: Enceladus Explorer
- Development of an acoustic navigation system to determine the position and explore the fore field within ice
- System successfully tested in several field and laboratory tests
- Final test: Blood Falls, Taylor Glacier, Antarctica, December 2014
- Usage of the developed sensors for future neutrino detectors
- Space mission to the Enceladus in about 30 to 40 years?

# Thanks!

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