EnEx-RANGE – Robust autonomous Acoustic Navigation in Glacial icE

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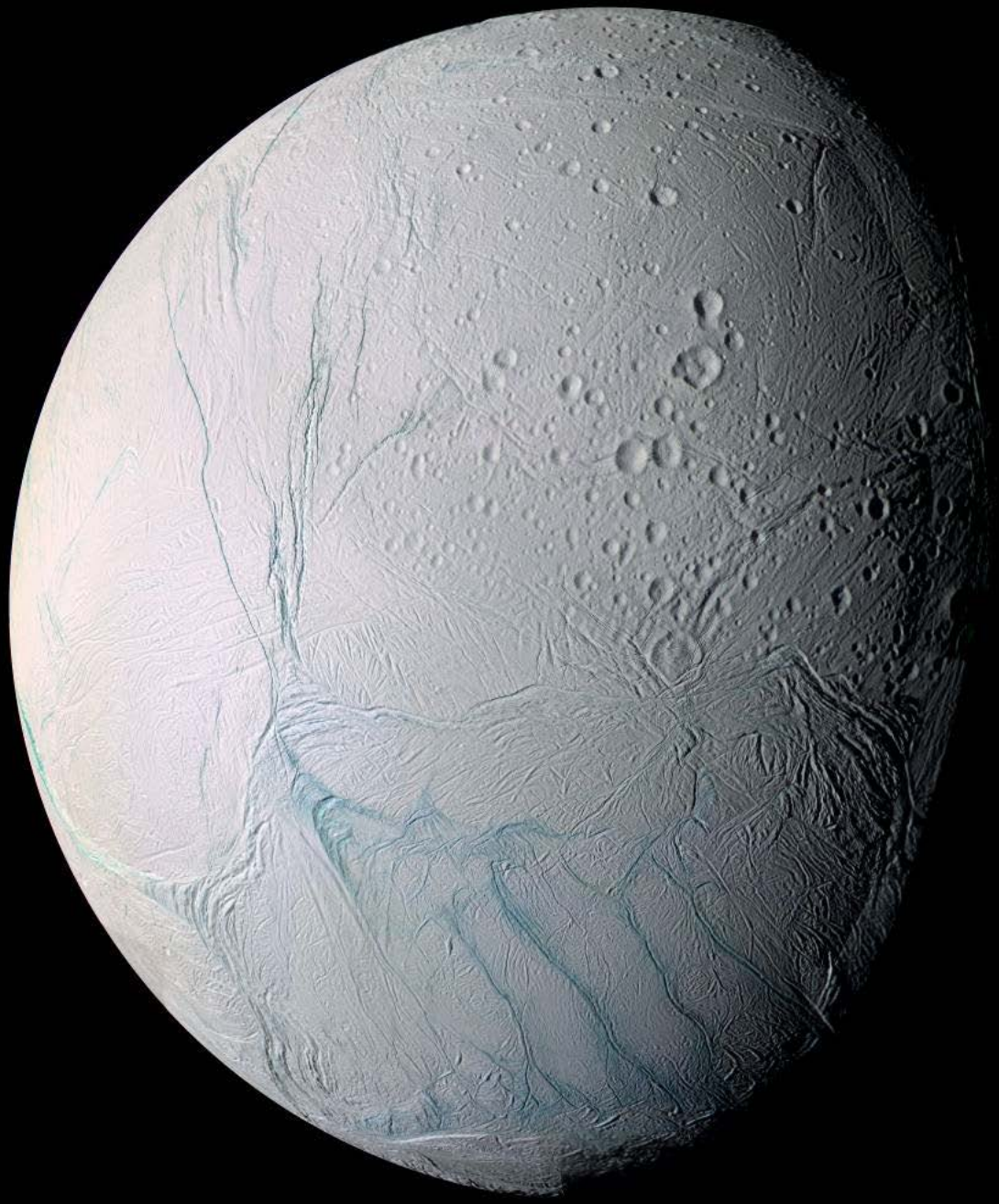
Outline

- Enceladus
- Enceladus Explorer – EnEx
- EnEx-RANGE
- Acoustic navigation
  - Forefield exploration
  - Positioning
- APU network
- Testing

- APUs – Autonomous Pinger Units
  next Talk by Simon Zierke

Enceladus



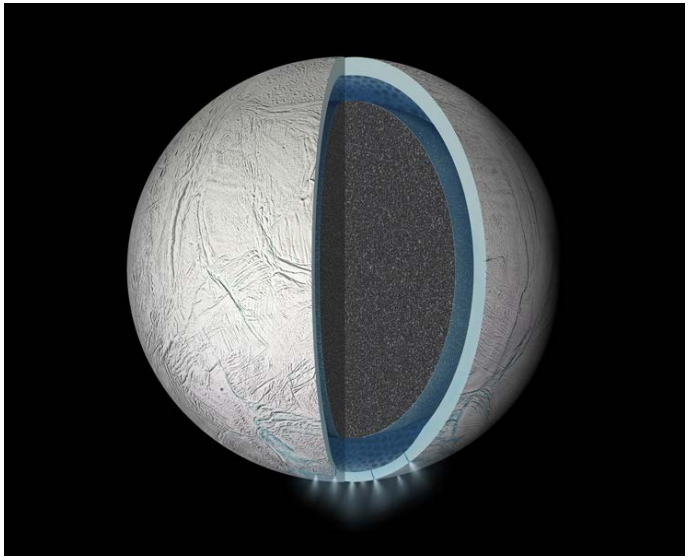
Enceladus

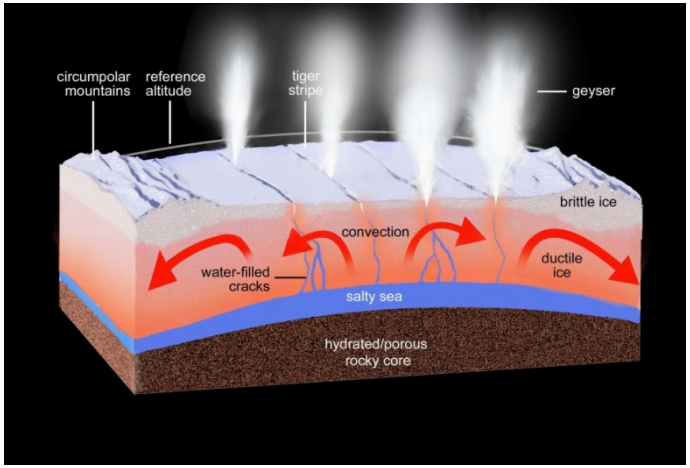
- Saturn moon
- Diameter 500 km

CASSINI mission

- Cryovolcanism at south pole
- Tiger Stripes
- Water files vents
- Organic Compounds
- Global Ocean below icy crust

Requirements for alien life fulfilled (water, organic compounds, energy)

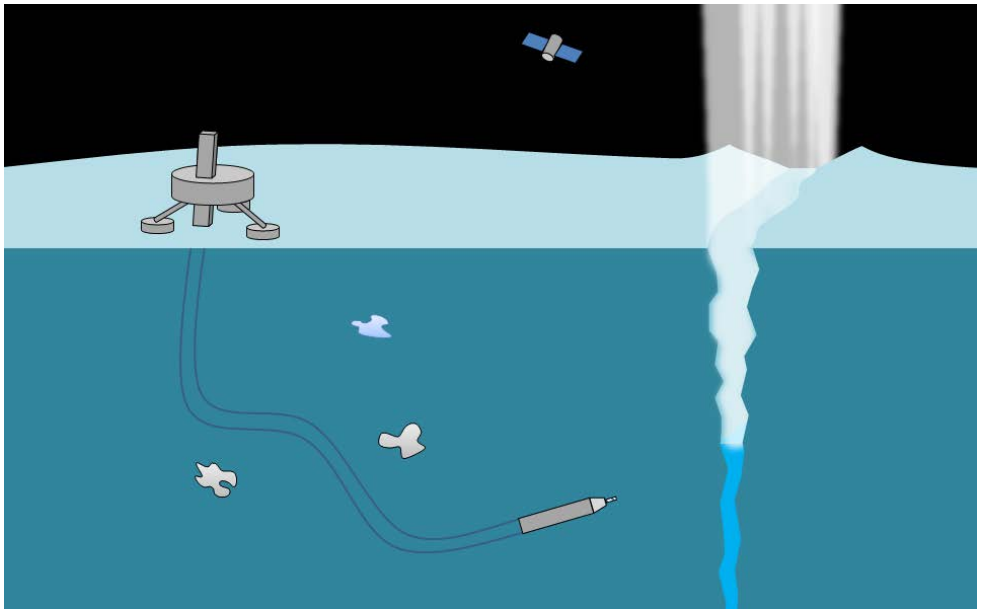




NASA/ JPL/ Space Science Institute

Enceladus Explorer Initiative

- DLR Space Administration
- EnEx mission:
  Is there life on Enceladus?
- Technology development for
  EnEx probe



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Projects within EnEx Initiative

1. EnEx project (2012 - 2015)

- Development of EnEx probe and navigation systems
- Test in glaciers (Alps and Antarctica)
- Successfully demonstrated in 2014 by probing a brine filled fissure Blood Falls, Taylor Glacier, Antarctica

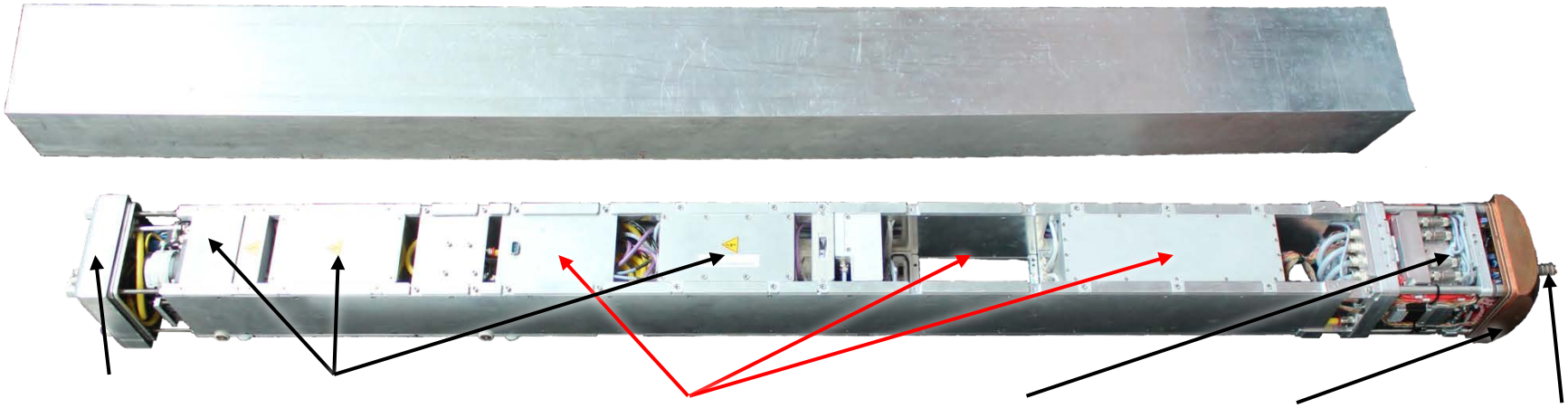
Since 2015

EnEx-CAUSE, EnEx-DiMice, EnEx-MIE, EnEx-NavEn, EnEx-nExT, EnEx-RANGE

EnEx Probe

- Carrier probe EnEx-IceMole
  Steerable due to ice screw and partial heating of melting head
- Navigation systems for
  Positioning,
  Determine heading,
  Scan fore field
- Decontamination und Sampling

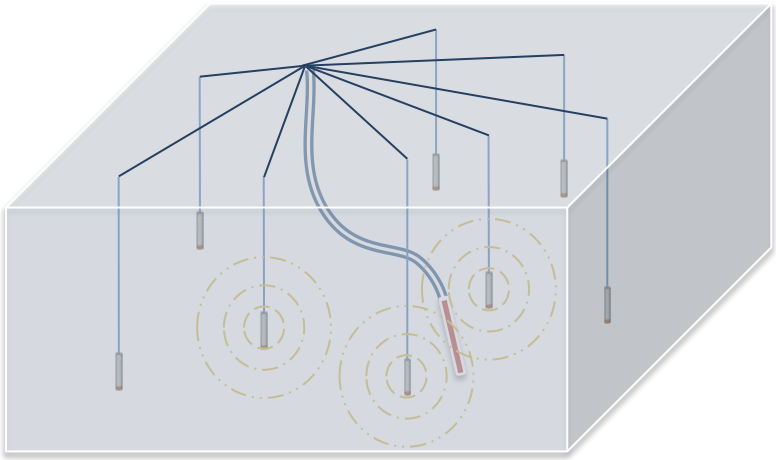
EnEx probe facts	
Velocity	100 cm/h
Dimensions	15x15x190 cm^3
Max. power consumption	3.600 W
Max. range	80 m
Curve radius	10 m



EnEx-RANGE

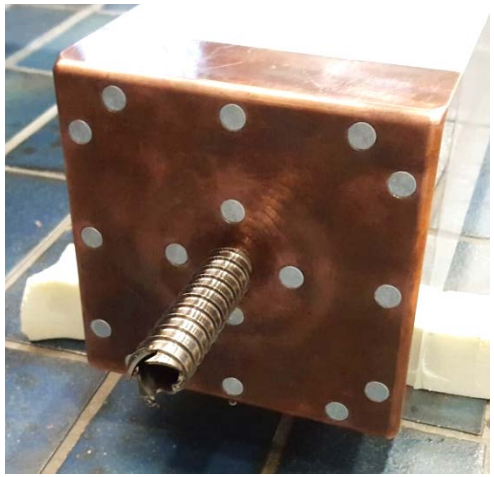
„Robust autonomous Acoustic Navigation in Glacial icE“

- Development of autonomous acoustic sensor network (APU network)
- Enhance acoustic navigation within EnEx probe
- Validation and demonstration in field (Glacier in Alps 2017 & 2018)
- Collaboration within EnEx Initative

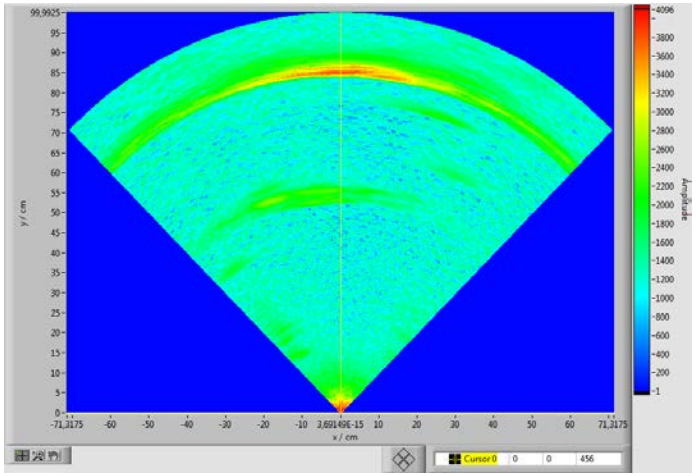


Acoustic forefield exploration

- Exploration of forefield in front of EnEx probe based on sonar
- Identification of objects (e.g. stones, crevasses, brine)

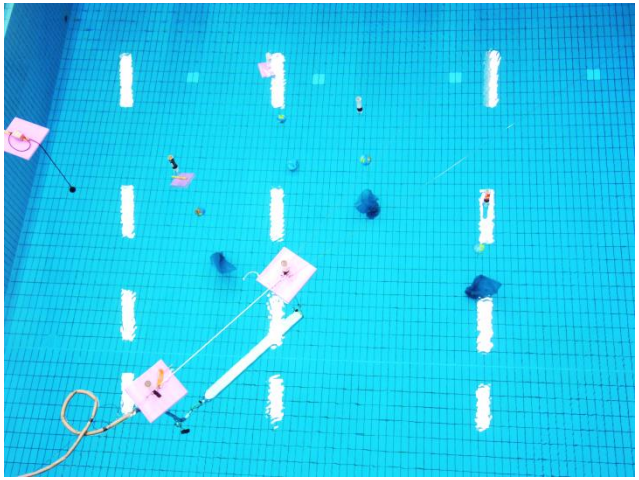


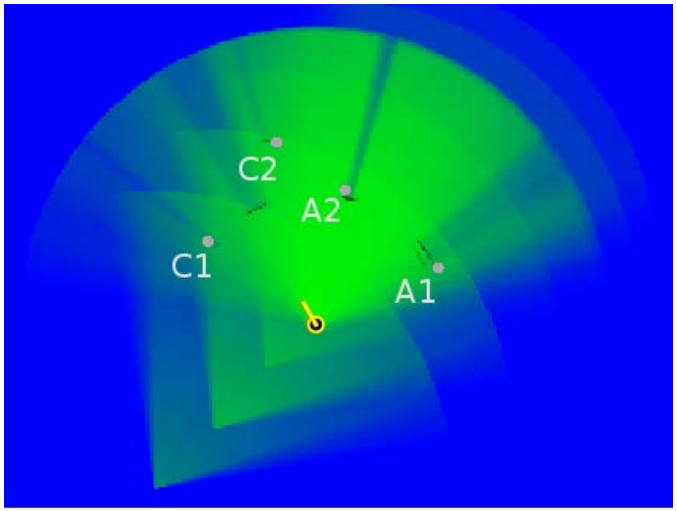
- Piezo sensors in probes head
- Phase driven signal generation
- Acquisition of reflections
- Visualization for operator



Acoustic forefield exploration

- Frequency range 10 – 400 kHz
- Emitter voltage 70 V
- Field of view typ. +/- 45°
- Angular resolution typ. 10 – 1° (freq. dependent)
- Range typ. 0.05 – 5 m (freq. and ice quality dependent)
- Power consumption typ. 10 W

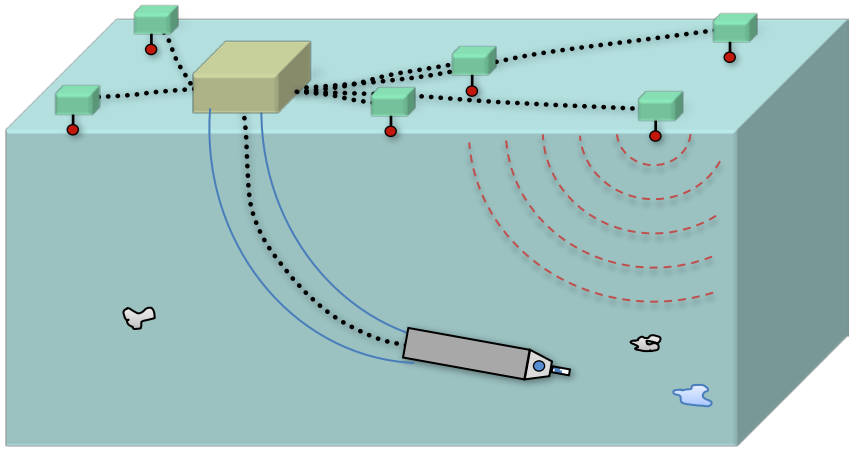


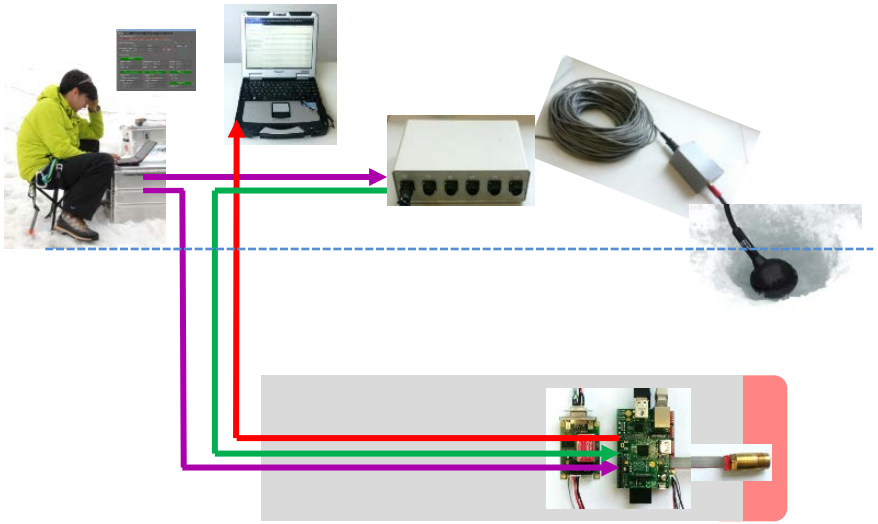


Acoustic positioning overview

Trilateration via acoustic signals:

- 6 pingers on reference positions at the glacier surface (University Wuppertal)
- 4 receivers with DAQ within EnEx probe
- Extraction of propagation times
- Measurement of speed of sound
- Trilateration
- Combination with inertial navigation systems (University Bremen)

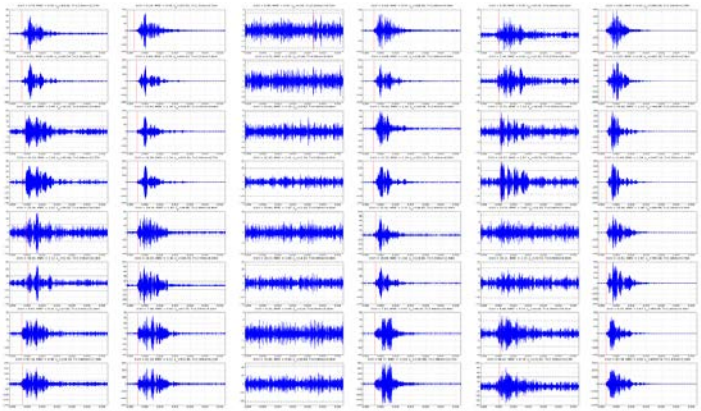




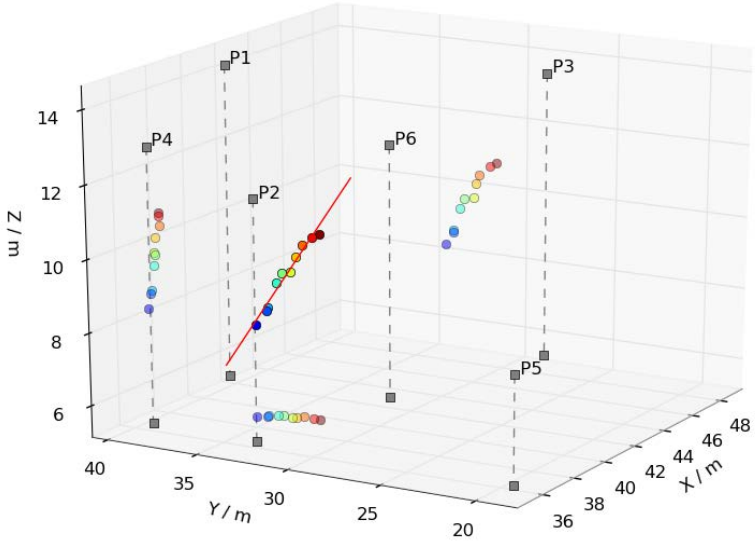
Acoustic positioning performance

- Successfully demonstrated in Alps and Antarctica
- Trajectories with acoustic measurements every 30-50 cm

- Typical precision ~ 20 cm



- Pinger lie on plane – not optimal
- Insertion of pinger manual by operator and time-consuming
- In ice anomalies only at glacier surface can be taken into account for geometry of pinger setup



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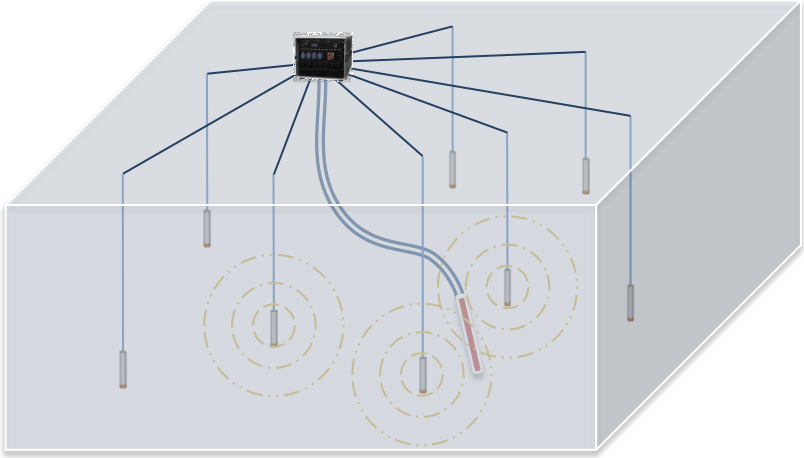
APU network

- Enhance pinger setup to acoustic positioning network
- Pinger transform to „Autonomous Pinger Unit“ – APU With local intelligence, sensors und melting abilities
- Autonomous optimization of APU network in size and positioning error
- EnEx probe navigation trough APU network



1. Full System Test at Langenferner, Alps, Italy, 2017

7 APUs & EnEx probe

Three scenarios

1. ARS phantoms (holes)
   -20° pitch, 20 m trajectory

2. Trough cracks
   -20° pitch, 20 m trajectory

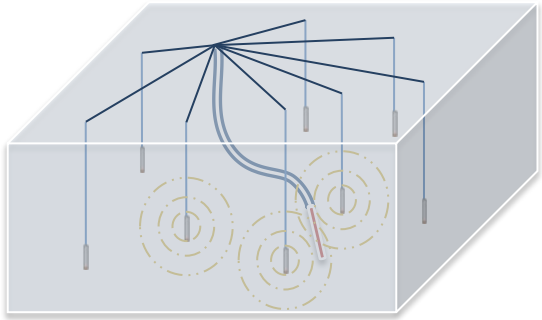
3. Network optimization
   -45° pitch, 30 m trajectory

2018: 13 APUs

Summary and outlook

- Search for alien life on Enceladus
- Development of in-ice navigation in EnEx

- Acoustic navigation systems developed and integrated into EnEx probe
- APU for network developed (next talk!)
- EnEx probe and APU Network successfully demonstrated



Thanks for your attention!

Gefördert durch:

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EnEx-RANGE

APUs – Autonomous Pinger Units

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Lars Steffen Weinstock, Christopher Wiebusch

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30.09.2017

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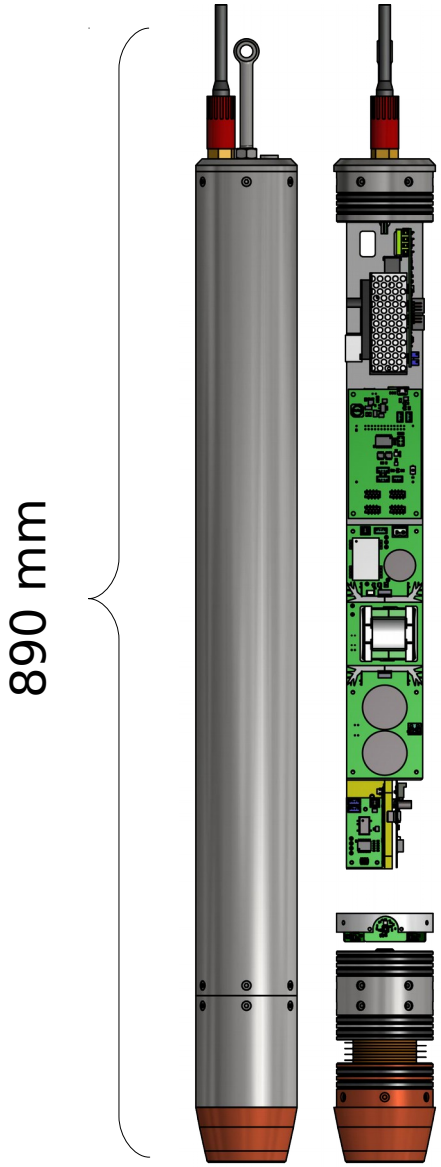
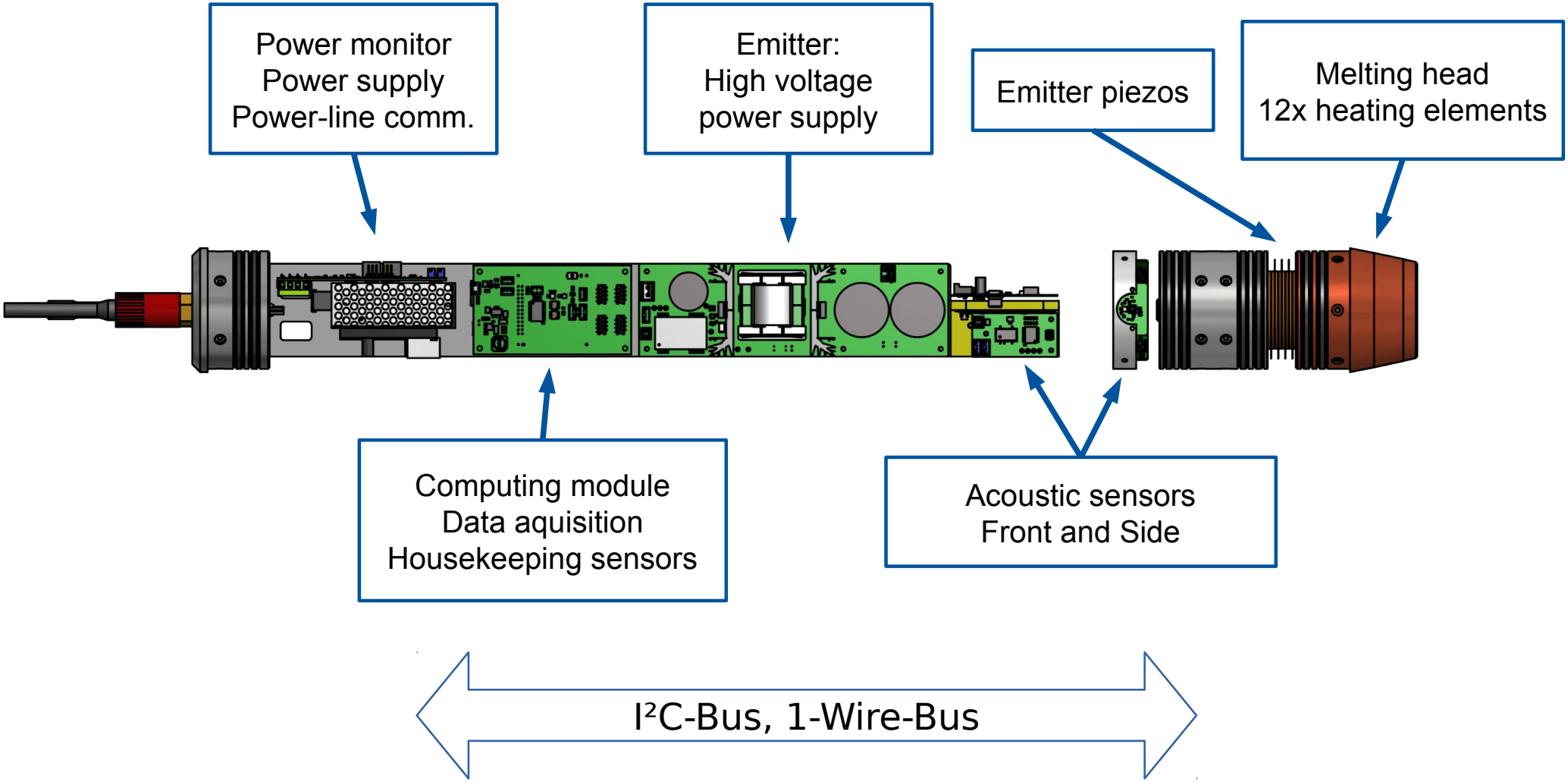
Melting probe – Autonomous Pinger Unit

- Autonomous Pinger Unit (APU)
  - Melting probe
  - Acoustic sensors and signal generation
  - Housekeeping sensors:
    - MARG sensor (9-dof)
    - Temperature (head, middle, back)
    - Pressure
    - Power

  - Depth rating: 200 m
  - Diameter: 80 mm
  - Length: 890 mm
  - Weight: 7 kg
  - Typ. Velocity: 3.3 m/h
  - Power: 2400 Watt

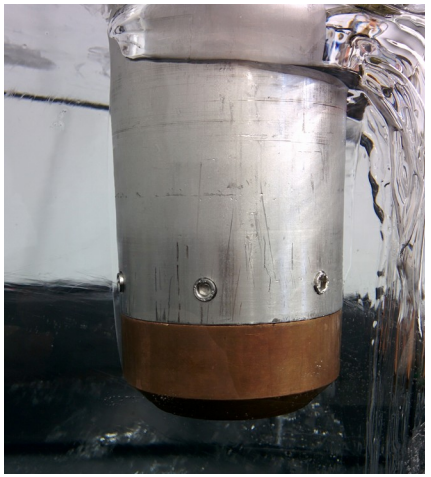


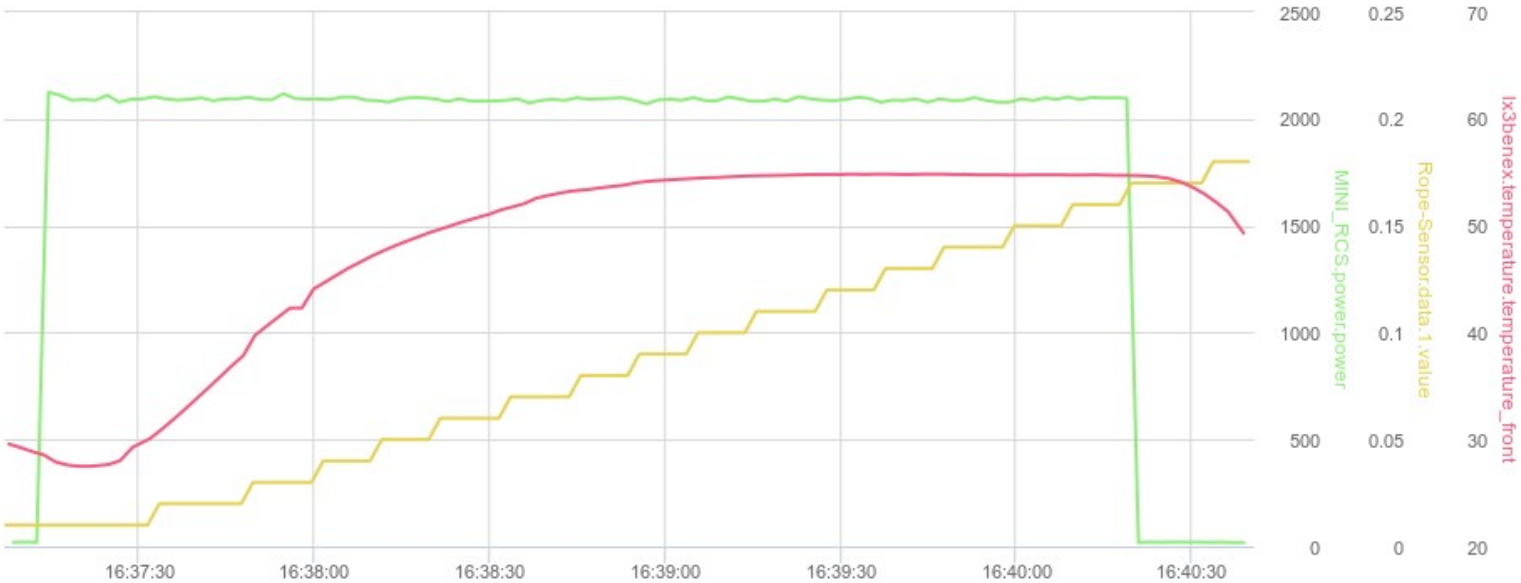
Components of our melting probe



Velocity test in laboratory

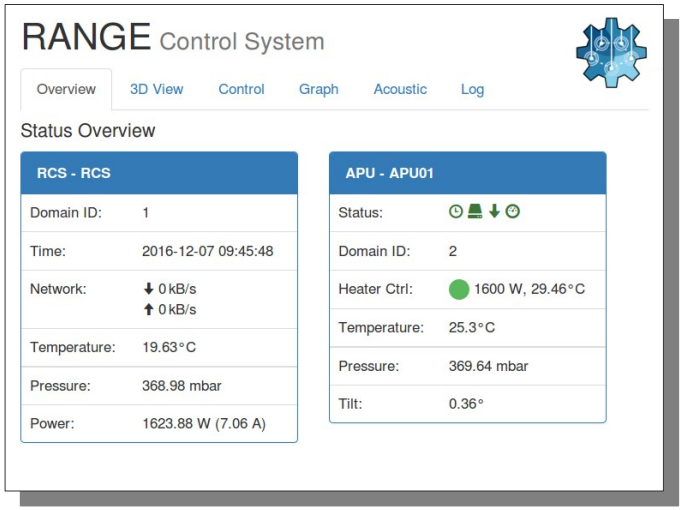
- Test in -18°C clear ice block
- Measured depth
- Constant 2400 Watt input
- 3.60 m/h @ 55°C constant head temperature
- Over 80% of maximal velocity (latent heat)





In field (minimal) setup

- Generator (3000 watts, 230 V)
- Melting probe
- Control box
- Computer or tablet or smartphone
- Cable and rope
- Setup time less than 15 minutes

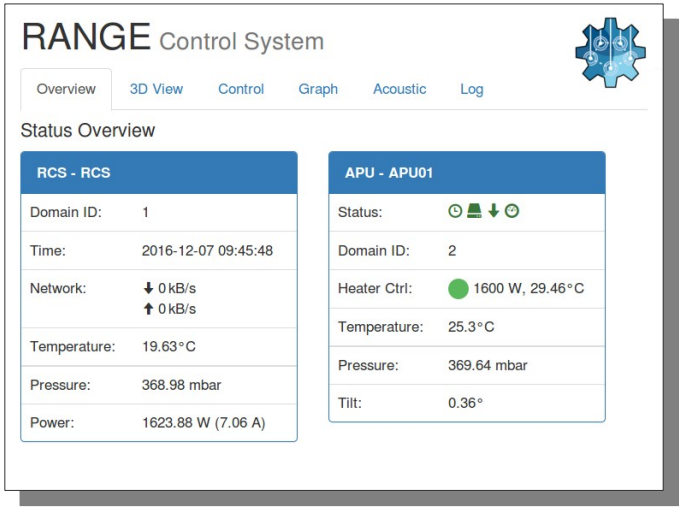


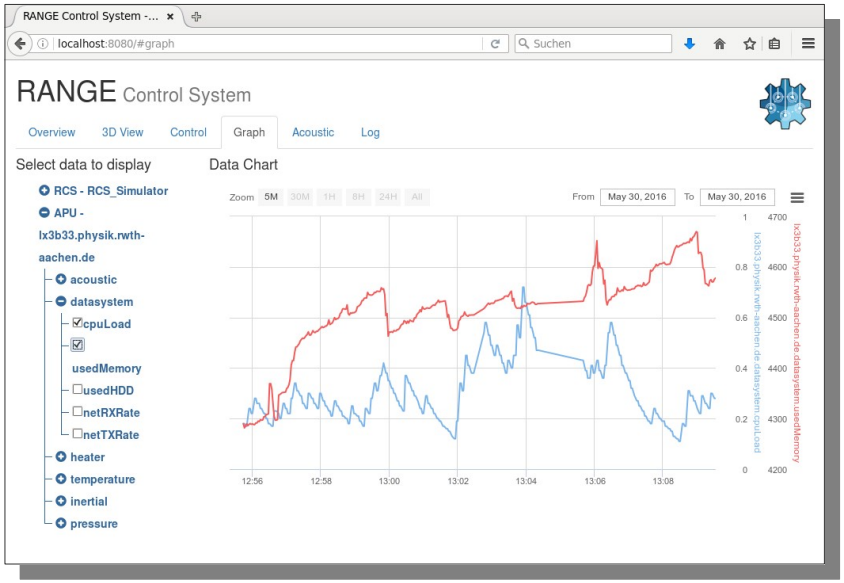
In field (minimal) setup

Item	Weight
Generator (Honda EU30is - empty)	58 kg
Melting probe	9 kg
60 m Cable and rope	15 kg
Control box	2 kg
Total	84 kg + fuel

Control box and control interface

- Data logging in database
  - Probe state
  - Air temperature
  - Air pressure
  - Power consumption
- Network connection to probe
- Automatic network discovery
- Control interface
  - Website
- WiFi access
  - Tablet or smartphone

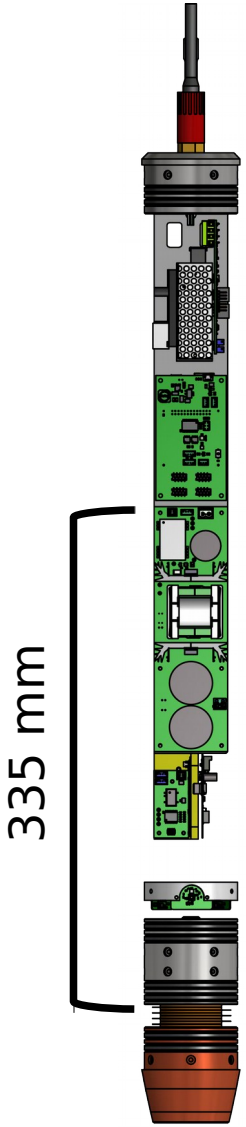




Summary and Outlook

- We developed a fast (3.3m/h) and lightweight Melting setup
- Tested in Antarctica in collaboration with ARIANNA
- Tested in Alps: Reached depths over 35m (bedrock?)
- 13 APUs for the next EnEx-RANGE field test

Reduced length version

- Remove acoustic instrumentation to reduce length
  - HV-power: -200 mm
  - Sensors : -65 mm
  - Emitter Mass: -70 mm
  - Total: -335 mm
  - Reduced Length: 550 mm

- Our first version
  - Length: 600 mm