Development of a digital acoustic sensor

EnEx – Enceladus Explorer

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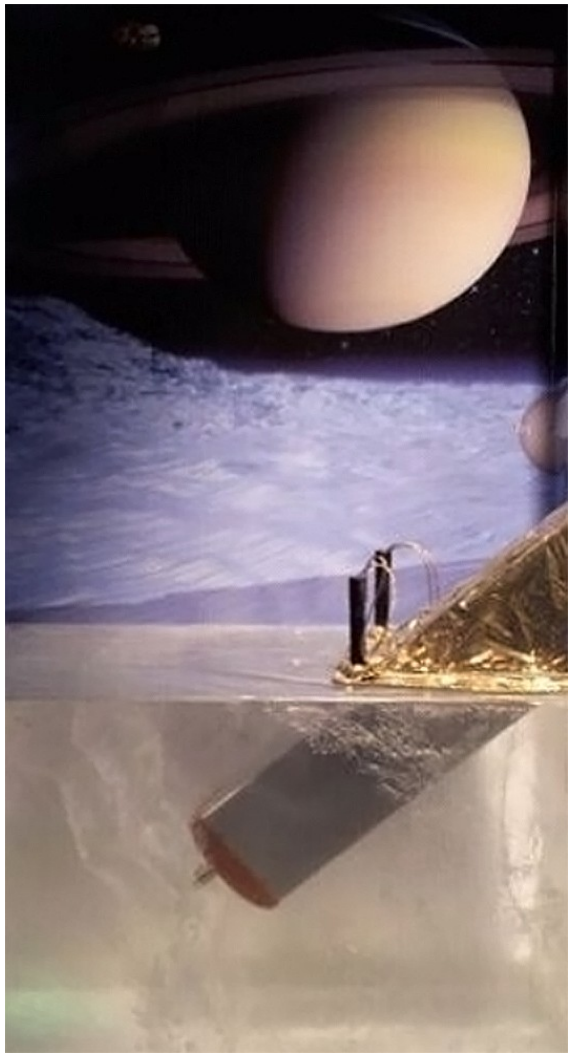
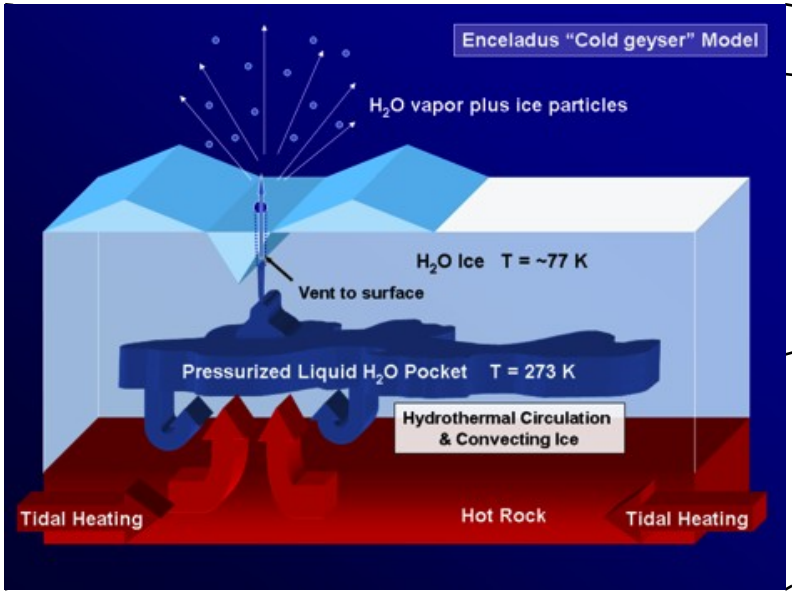
Outline

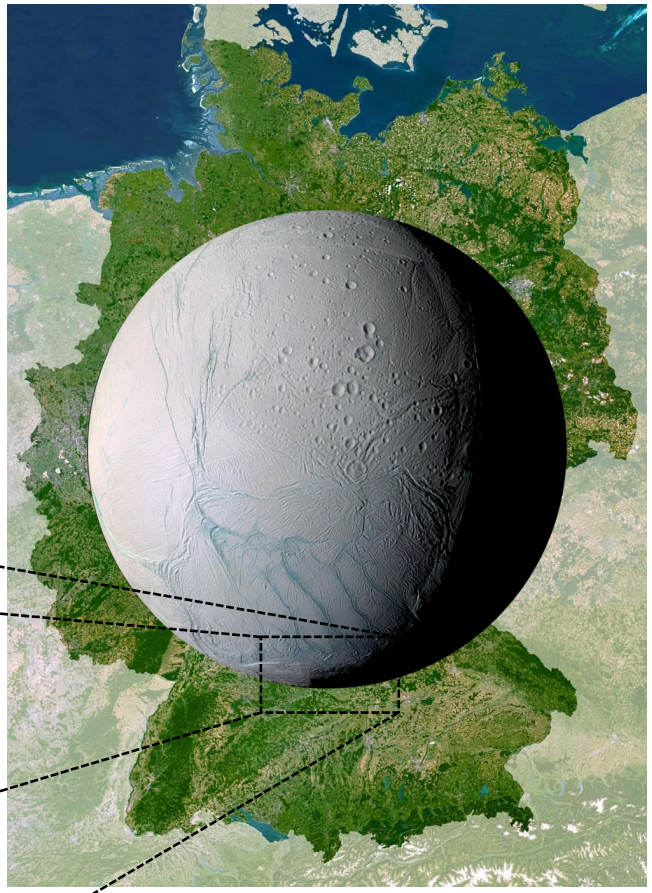
- Search for life on Saturn moon Enceladus
- Acoustic Positioning System
  - Overview
  - Sensor design
  - Software filter
- Future developments: RANGE
- Summary & outlook



Search for life on Saturn moon Enceladus

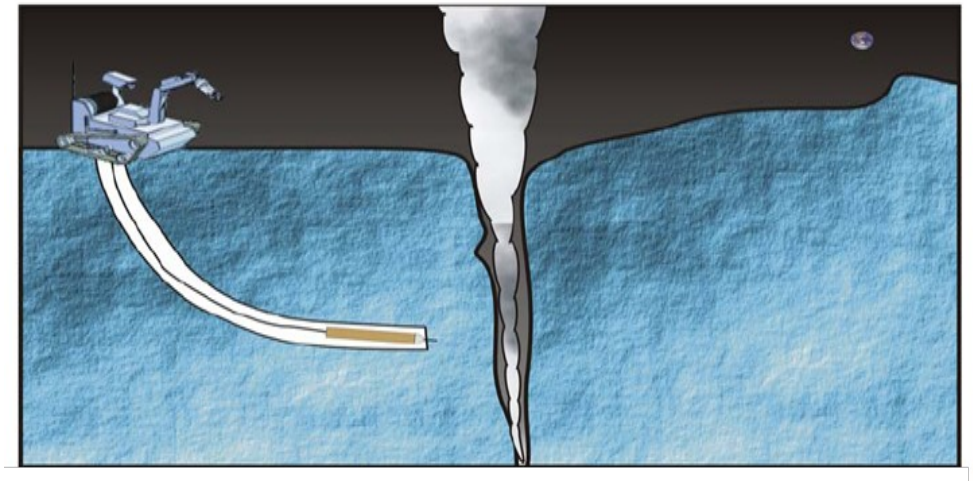
- 500km Diameter
- Covered by an water ice shield
- Cryovolcanic activity in the south polar region
- Organic molecules measured by Cassini
- Evidence for subglacial ocean

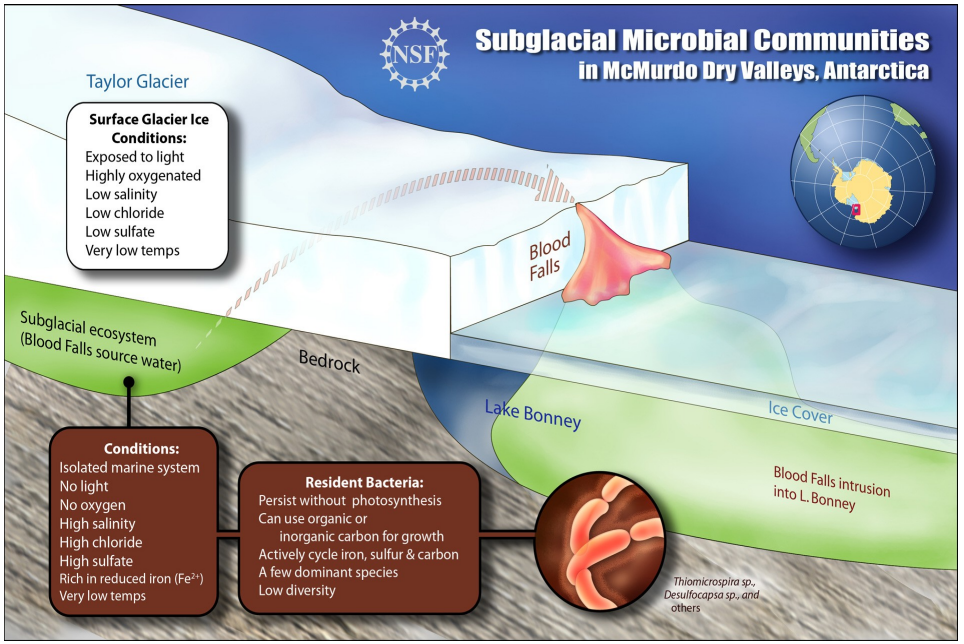




Motivation of the Enceladus Explorer Project (EnEx)

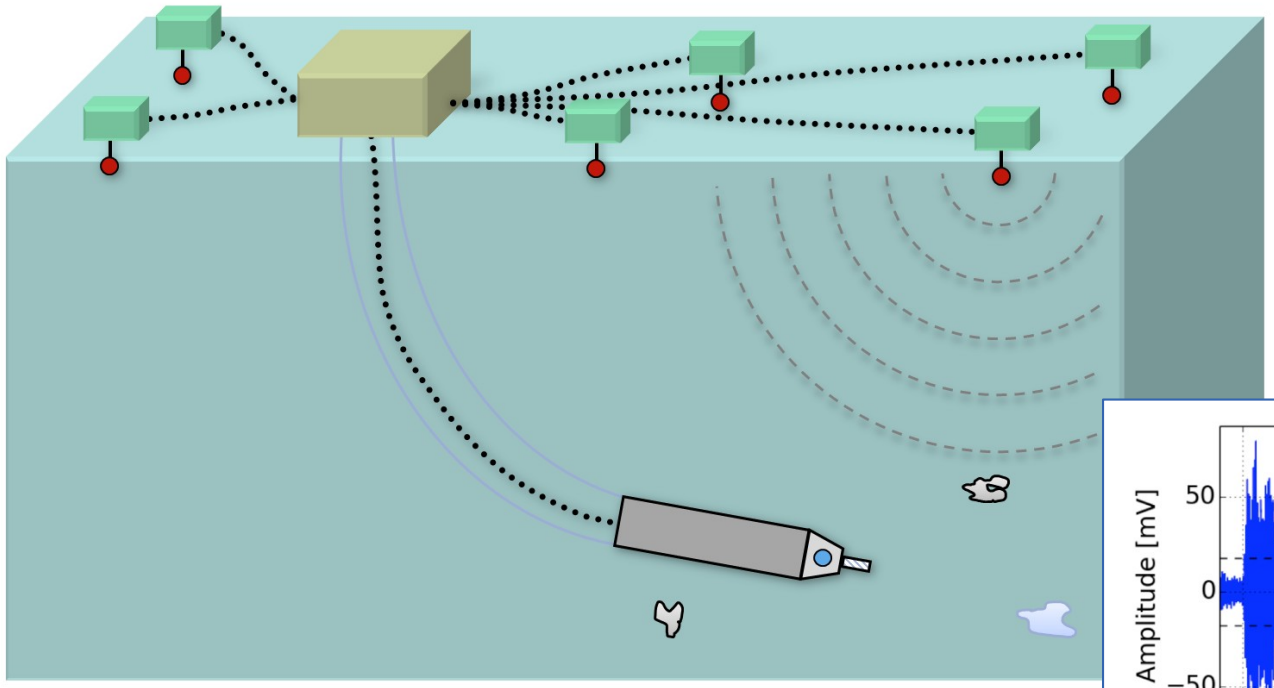
- Search for life: Tip vent and take a liquid sample
- Feasibility study / technology development for a future space mission funded by DLR
  - Development of a specialized steerable probe
  - Development of in-ice navigation methods
- Demonstration in terrestrial scenario at Blood Falls, Antarctica
  - Contamination free sampling from a fissure ~20m below surface

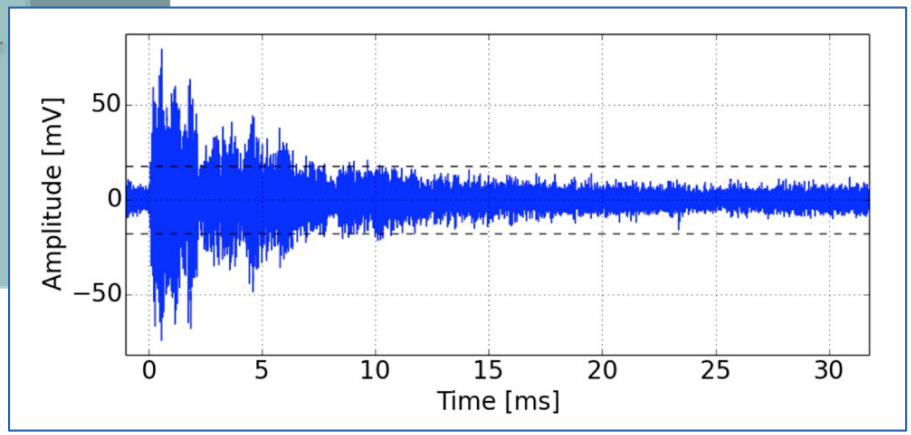




Acoustic Positioning System (APS)

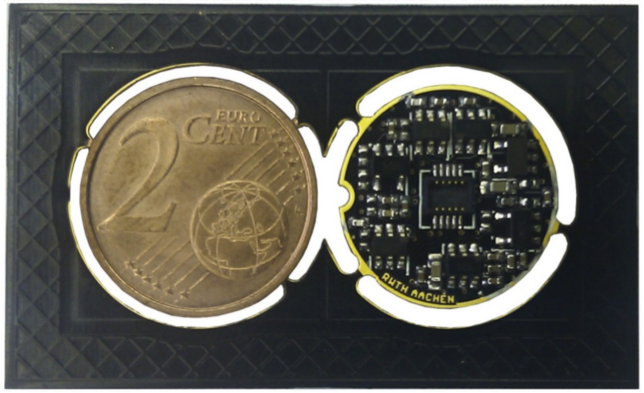
- Determination of the absolute probe position by trilateration
- 6 ultrasonic emitters (~18 kHz) with central control unit on surface
  Developed by BU Wuppertal
- 4 digital sensors coupled to melting head

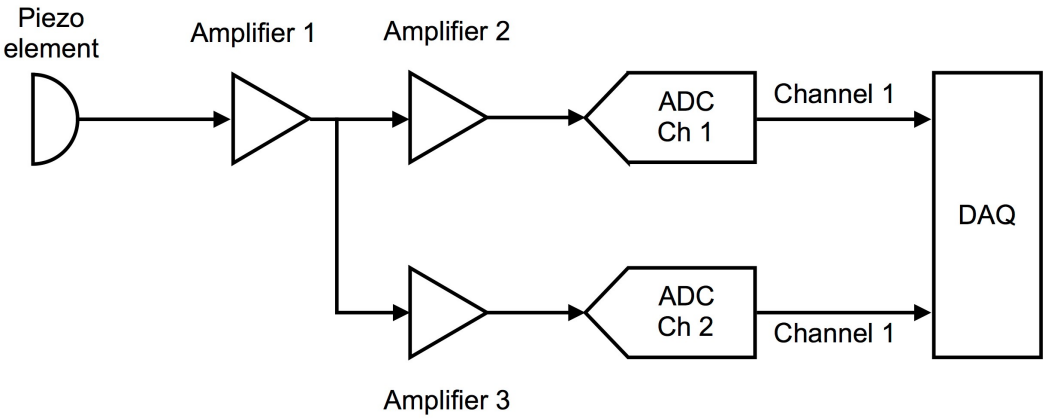


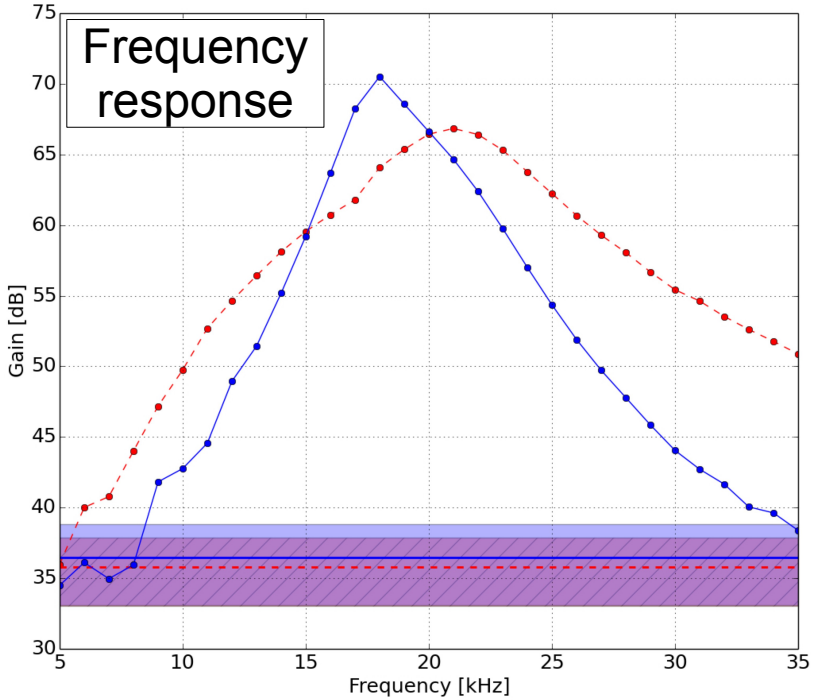


APS Sensor Design

- Sensors optimized for ultrasonic signals (~18kHz)
- Small size: Ø 17,7mm x 13mm
- Electronics: Two stage amplifier
  - Broad / narrow passband
- 2 MS/s, 12-bit ADCs
- Digital LVDS output

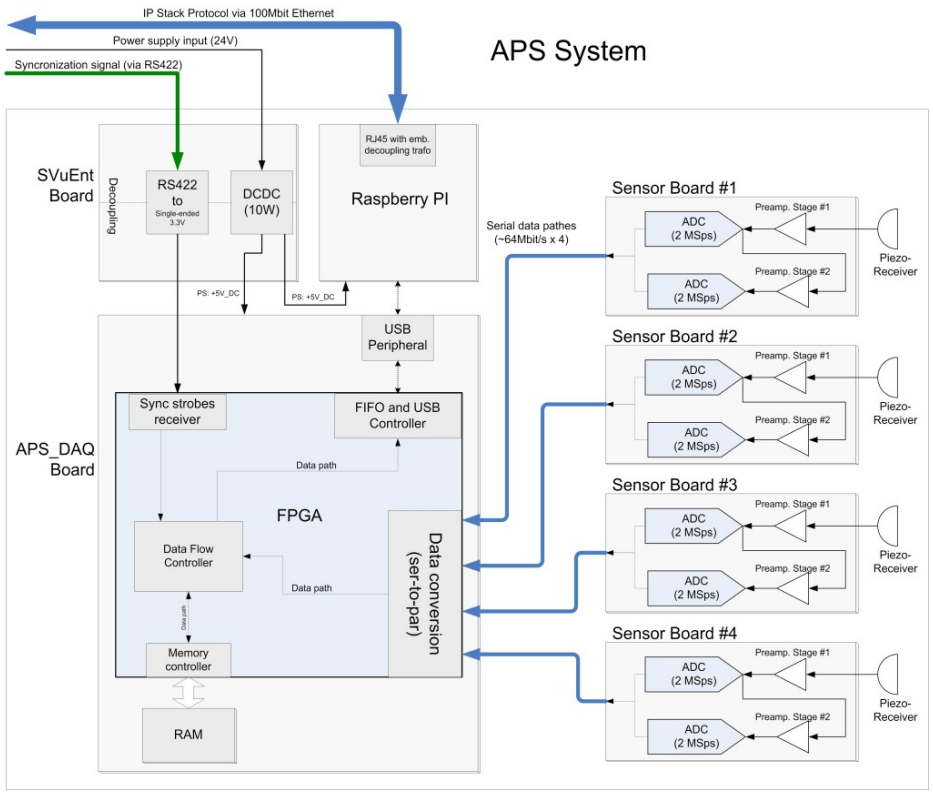


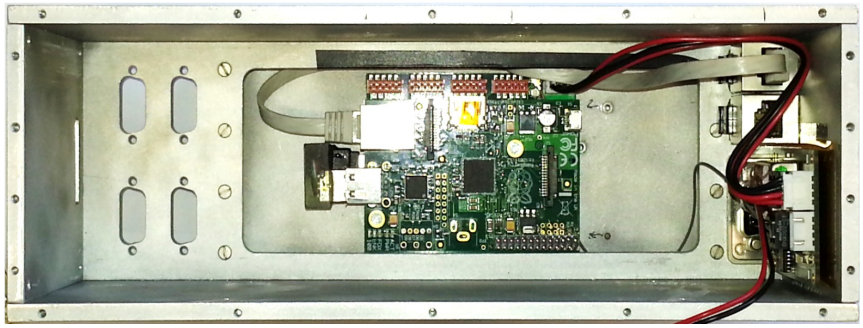


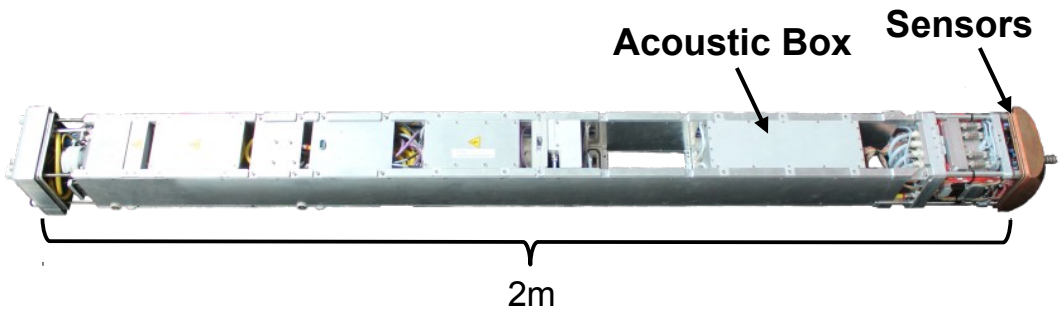


APS – Data Acquisition

- LVDS output from sensors
- Data acquisition with FPGA (Spartan 6, 16MB RAM)
- Synchronization with surface components
- Readout and processing with embedded PC (Raspberry Pi B)

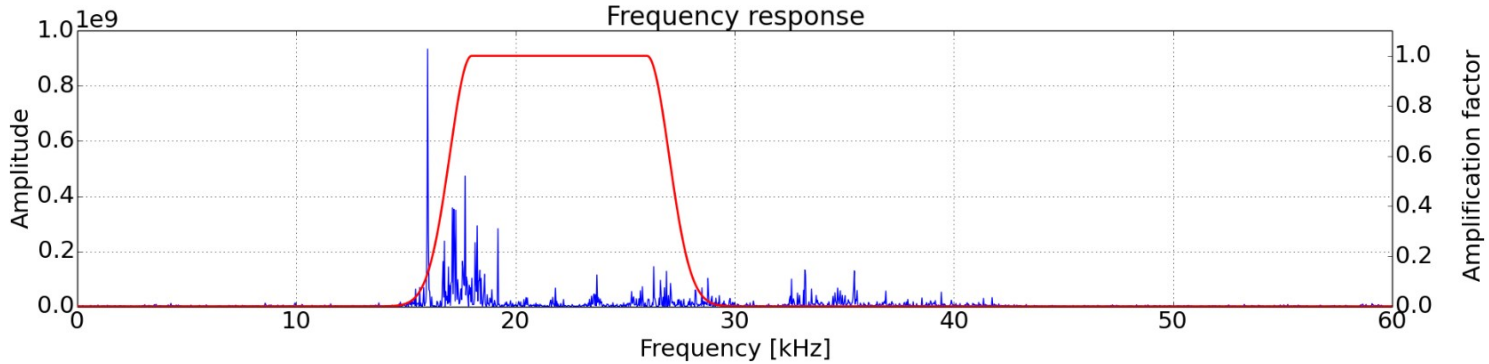




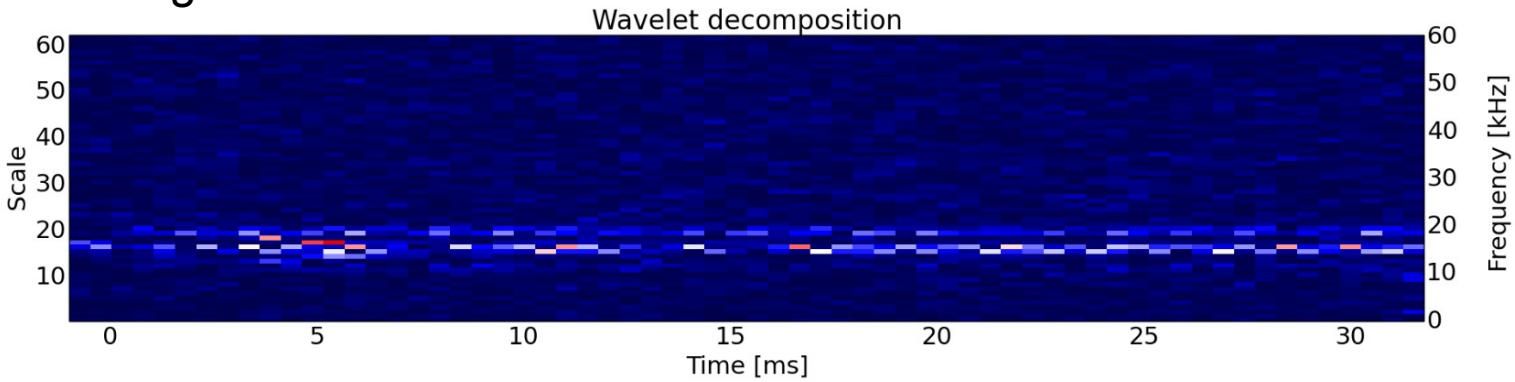


Software Filtering and Processing

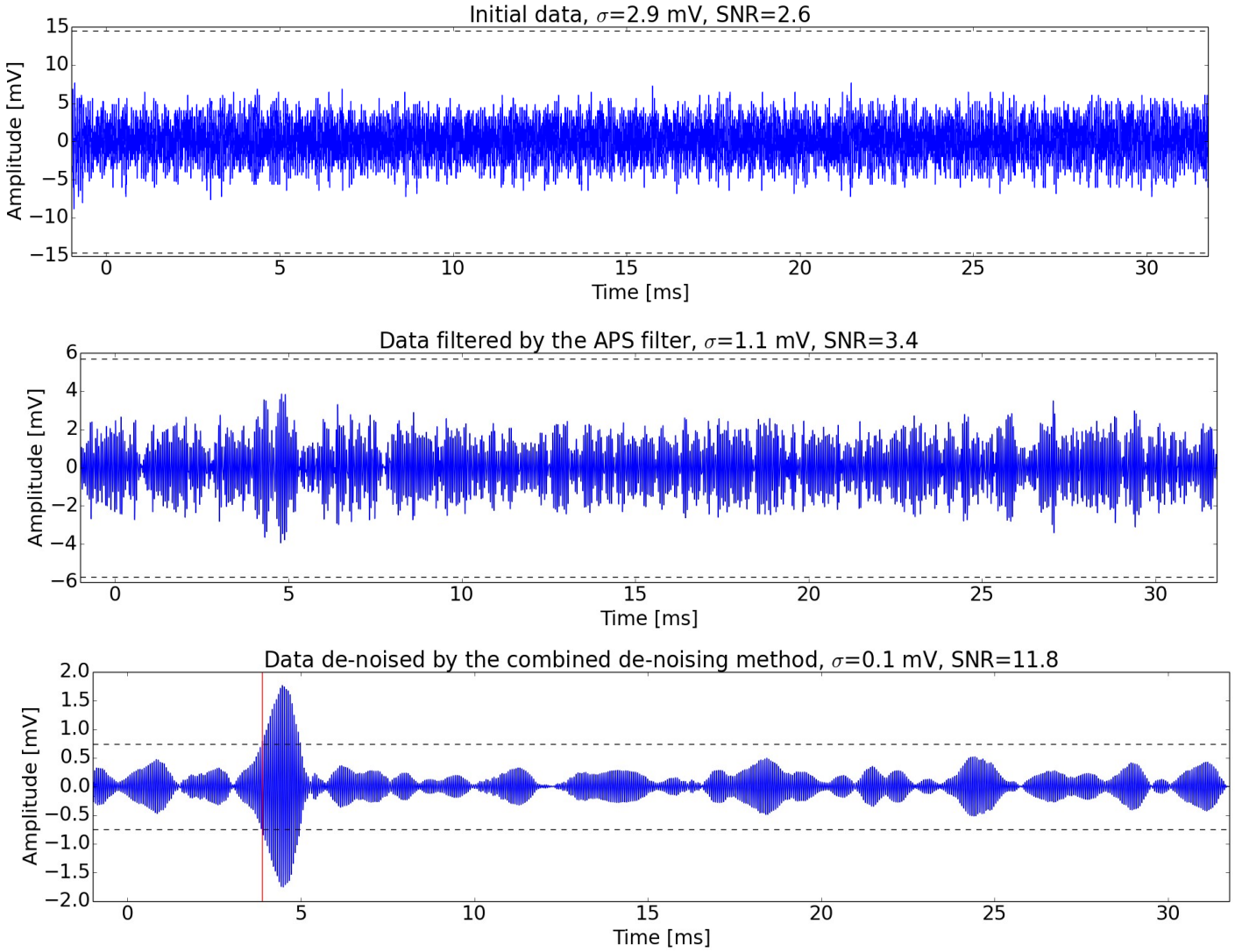
- Increase SNR by noise filtering
- Fast Fourier Filter



- Wavelet based software filter
  - Not frequency depended
  - Filters out gaussian noise



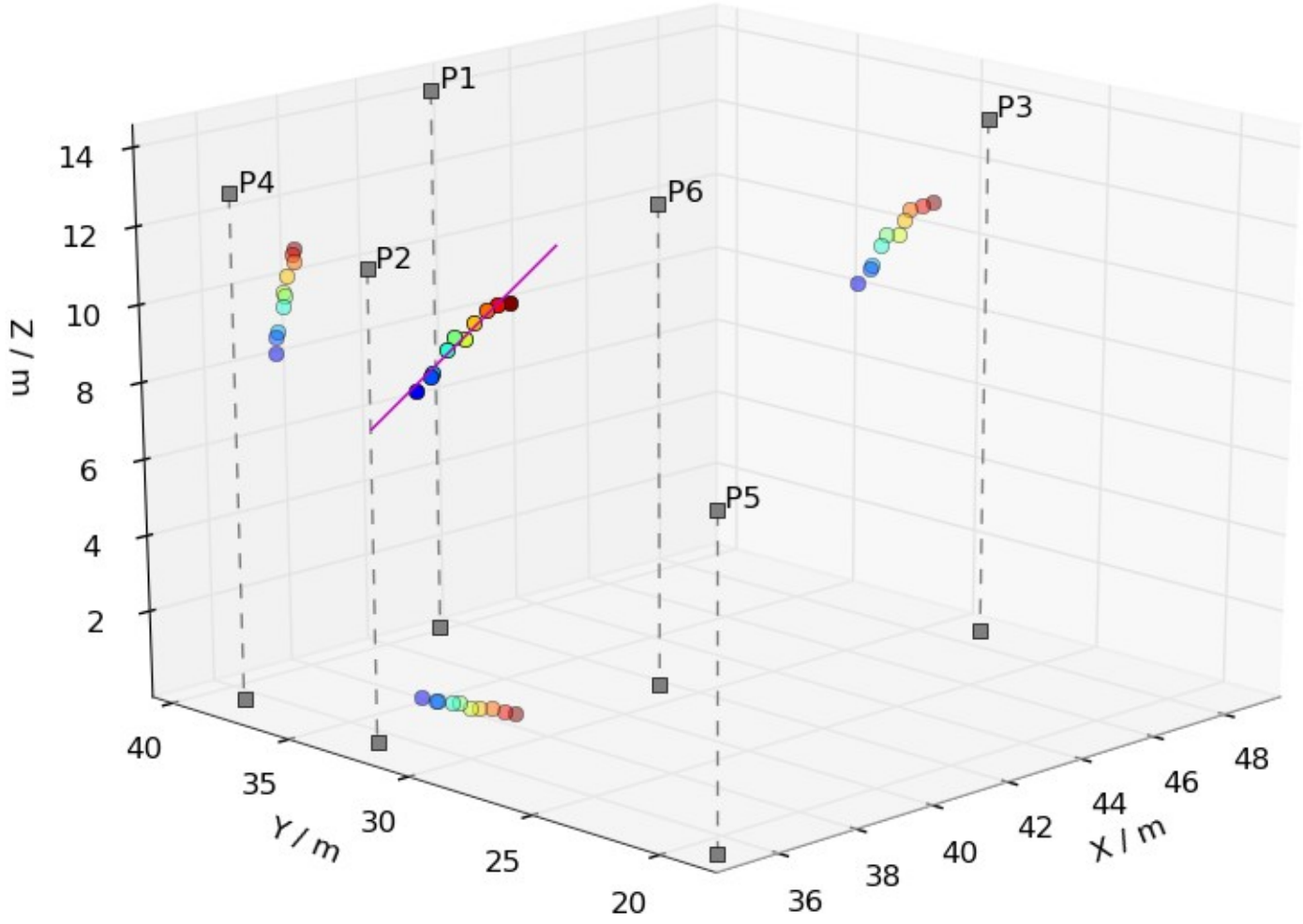
Software Filtering and Processing



Increase in SNR of about 4.5

Results: Trajectory Reconstruction

- Reconstruction of trajectory recorded during fieldtest 2014 in Switzerland
- Position resolution < 0.2m in firn ice



Future: RANGE

- RANGE – Robust Autonomous Navigation in Glacier Ice
- Development of a autonomous inteligent acoustic sensor
- Likely funded by DLR for 4 years
- RWTH Aachen
  - Physics Insitute III B
  - Institute of Information Management in Mechanical Engineering (IMA)
- Equip Moduls with:
  - Melting head
  - Acoustic sensors & emitter
  - Enviromental sensors
  - Digital communication
- Self optimization and calibration of acoustic sensor/emitter network

Outlook: IceCube Next Generation

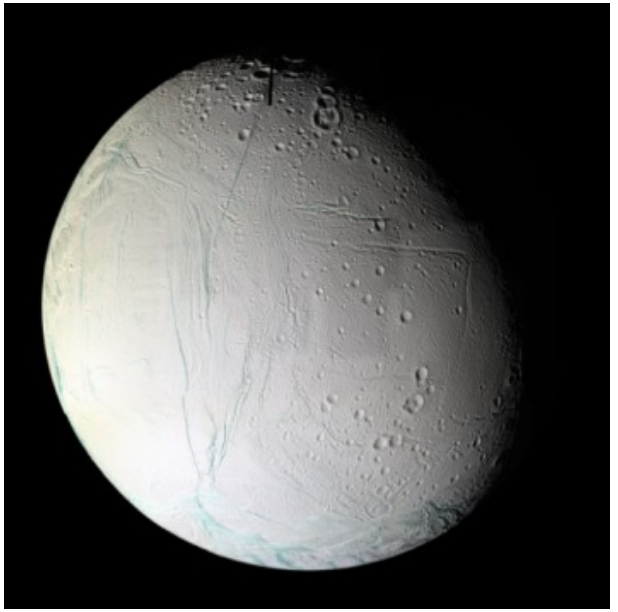
- 1 APS sensor per DOM
- Cost per sensor: 100 €
  - Electronics: 80 €
  - Piezo: 10 €
  - Mechanics: 10€
- Large savings through mass production

- Achieve independend position determination
- Enviromental information
- Potential of acoustic neutrino detection

Summary & Outlook

- Development of an acoustic in-ice navigation system for position determination
- Sensitive digital acoustic sensor module and readout electronics
- Position determination of probe in firn ice with accuracy < 0.2m

- Acoustic Neutrino Detection / Position determination
- Space mission in 30 – 40 years (?)

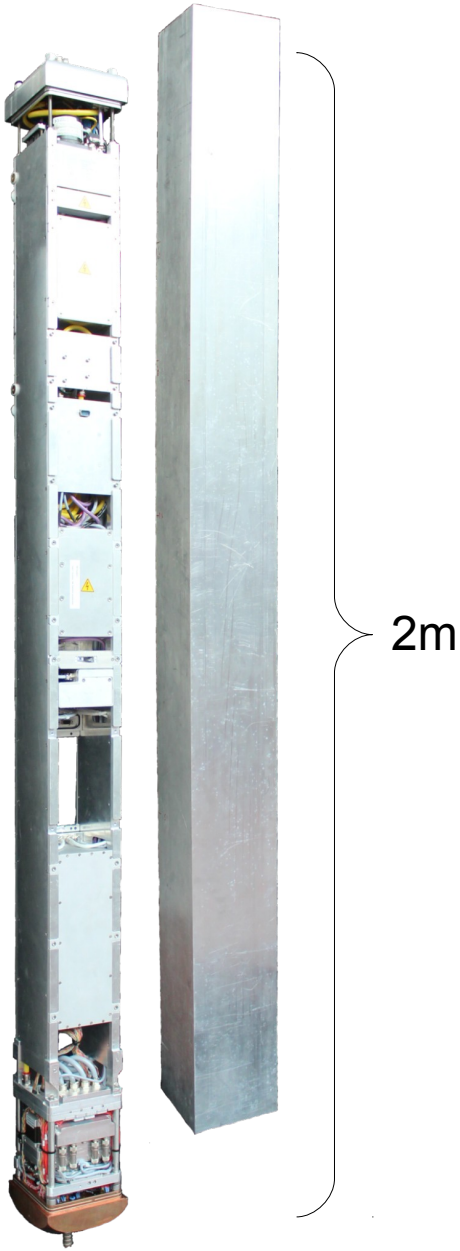


Thank you

IceMole – the ice probe in overview

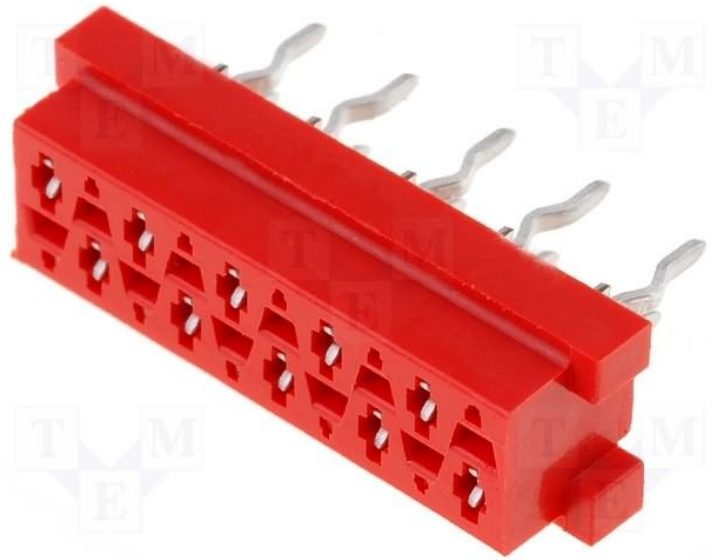
- Melting probe with ice screw
- Steerable through the ice
- In-Situ decontamination and sampling
- Carrier system for payload
- Subsystems for attitude and position determination and forefield exploration
  - Inertial Nav.: IMU and magnetometer
  - Acoustic navigation

Current design	
Dimensions	15 x 15 x 200 cm^3
Velocity	1 m/h
Max. power consumption Front heater	3 kW
Max. range	≈ 80 m
Curve radius	10 m



Sensor: Pin Assignment

- 2 MS/s
- 12 Bit
- LVDS
- Pin Assignment: 10 Pin MicroMatch Connector
  - +5 V
  - GND
  - ChipSelect (P/N)
  - Data ADC 1 (P/N)
  - Data ADC 2 (P/N)
  - Clock (P/N)



FT-1: Attenuation length

- Determination of the attenuation length in firn ice for 20 kHz