

# Development of an XRF Borehole Probe for Depths up to 500 m

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# Why Borehole Probe Development ?

- Exploration is done by borehole drilling
  - Core Drilling
    - Cores can be analyzed with hand held XRF devices
    - Later analysis in laboratory
    - Time consuming
    - Very expensive
    - Very precise

# Why Borehole Probe Development ?

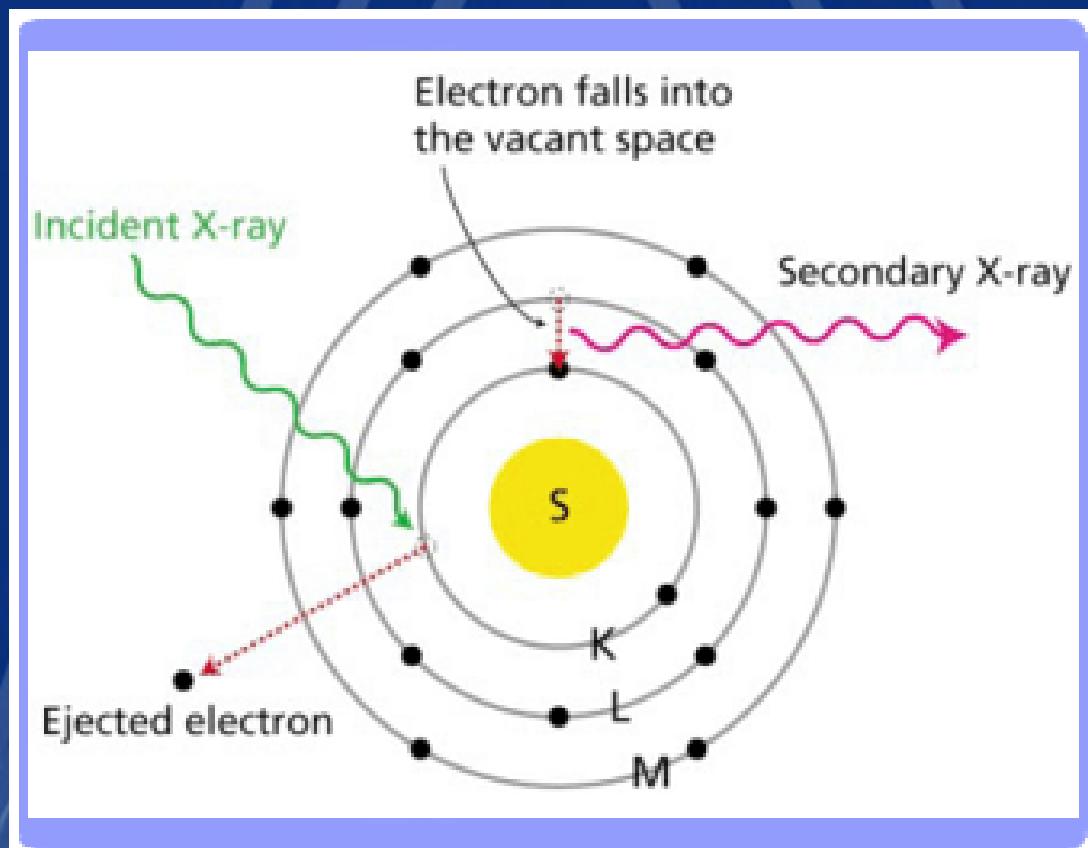
- Exploration is done by borehole drilling
  - Conventional Drilling
    - Drill debris is collected as sample
    - Evaluation of subsamples is done in laboratory
    - Analysis in laboratory is time consuming and costly
    - Samples represent average of certain part of the drilled hole (e.g. 20 m)
    - Poor depth resolution
- Conventional methods do not allow fast action according to results

# X-Ray Fluorescence

- Suitable for Elemental Analysis
- Present Status:
  - XRF measuring devices in operation under various conditions
    - On-belt measurement
    - Slurry measurement
    - Hand held devices for sample investigation
  - Logical step: Use of XRF for Borehole Logging

# X-Ray Fluorescence

- Basic Measurement Principle



# XRF Probe: Feasibility

- Prototype Development:
  - Borehole Probe
    - Depth up to 30 m
    - Not pressure proof
    - Width 90 mm
    - Cable based real-time data transmission to surface
    - Designed for blasthole logging

# XRF Probe: Feasibility

- Prototype Development:
  - Based on standard XRF Analyzer
  - Big drum
  - Electronics included inside drum
  - Purpose: feasibility testing



# XRF Probe: Feasibility

- Prototype Development:
  - Sensor length 600 mm
  - Standard X ray tube
  - Standard X ray sensor
  - No center alignment
  - No adaption to changing borehole diameters



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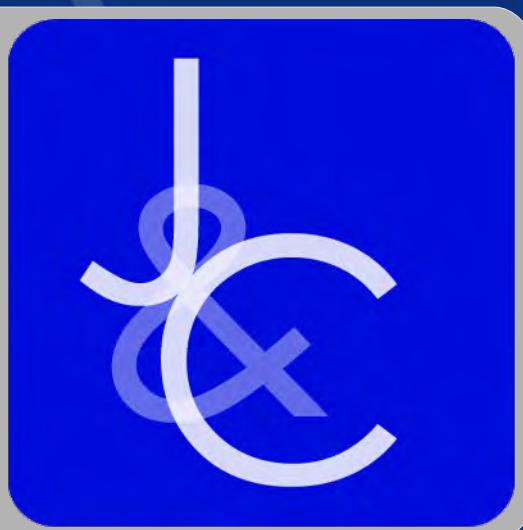
# XRF Probe: Feasibility

- Prototype Development:
  - Control of measurement is done with a laptop using WLAN



# XRF Probe: Development

- Development of Industrial Version:
  - Borehole Probe
    - Joint development with GFZ, Potsdam, Germany



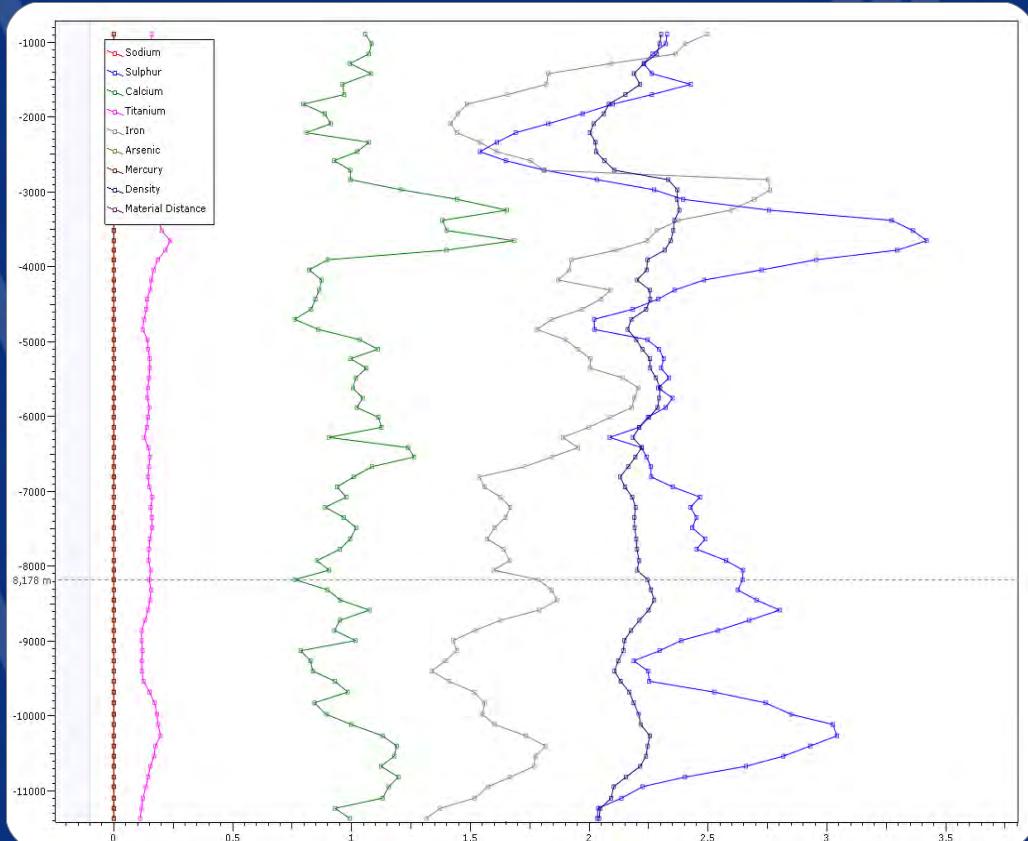
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# XRF Probe: Development

- Development of Industrial Version:
  - Borehole Probe
    - Depth up to 500 m
    - Withstands pressure up to 5 MPa
    - Width 53 mm
    - Length approx. 2.000 mm
    - Cable based real-time data transmission to surface

# XRF Probe: Development

- Borehole log
  - Logging speed variable
    - Accuracy increases with decreasing speed
    - Raw Sensor Data acquisition
  - Simultaneous logging of different elements
  - Density log



# Borehole Probe

## Challenges of high depth

	Prototype	Final Development
Depth	30 m	500 m
Temperature	Up to 40 °C	Up to 70 °C
Borehole Width	90 mm	53 mm
X-Ray Power Supply	Ground Level	Inside of Probe
Data Transmission	Ethernet	DSL
Data Transmission Range	30 m	500 m
Scan Speed	10-200 mm/s	10-200 mm/s

# XRF Probe: Width

- All components must fit into the probe
  - Restriction
    - Available space: 43 mm inner diameter
  - Requirements
    - Development of a special power supply for voltages up to 50 kV
    - Development of an adapted X-ray sensor
    - Use of a miniaturized X-ray tube
    - Development of a high speed data transfer using standard winch cables

# XRF Probe: Depth

- Increasing outside temperature with depth
  - Restriction:
    - All components must withstand increased temperature range
  - Requirements:
    - Excess heat has to be absorbed or exchanged to the environment
      - Heat pipes
      - Peltier cooling for sensor and electronics
      - Intelligent energy management

# XRF Probe: Electronics

- All electronic components had to be adapted
  - Sensor
    - Adaption of an industrial available sensor
    - Sensor module with new supply board

# XRF Probe: Electronics

- All electronic components had to be adapted
  - X-ray power supply
    - Commercially available power supplies (50 kV, 50 W) do not fit into tube
    - Complete new development required

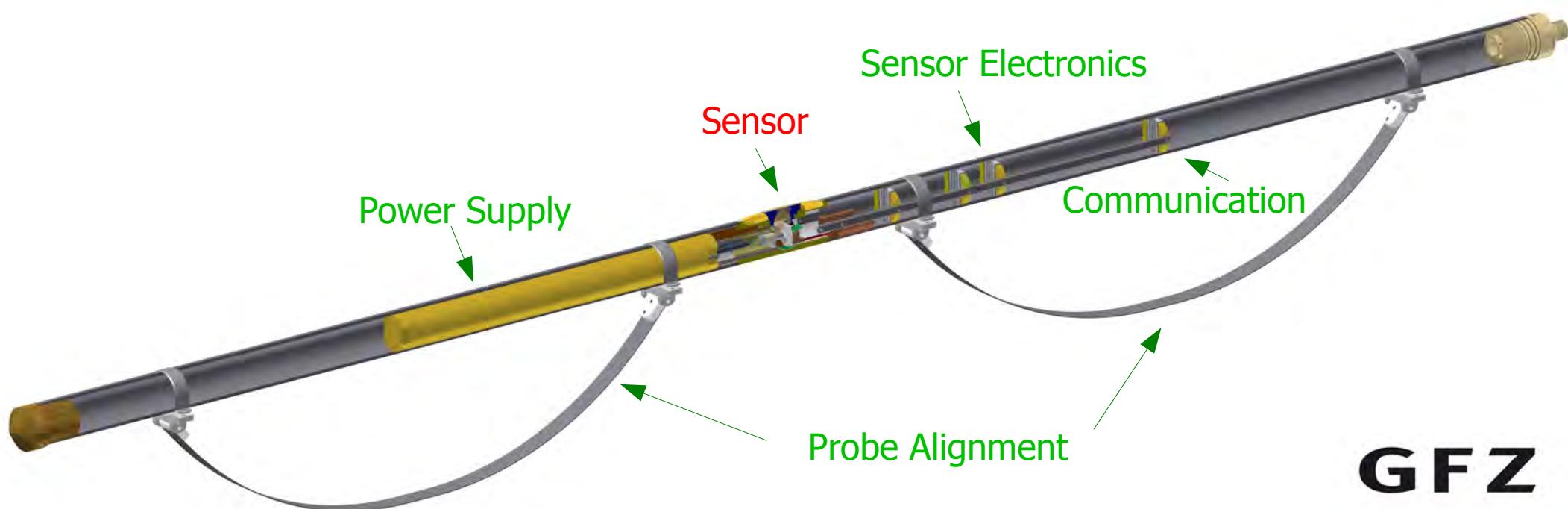
# XRF Probe: Electronics

- All electronic components had to be adapted
  - Data transmission
    - Adaption of existing ADSL techniques
    - Commercially available modules do not fit into tube

# XRF Probe: Physics

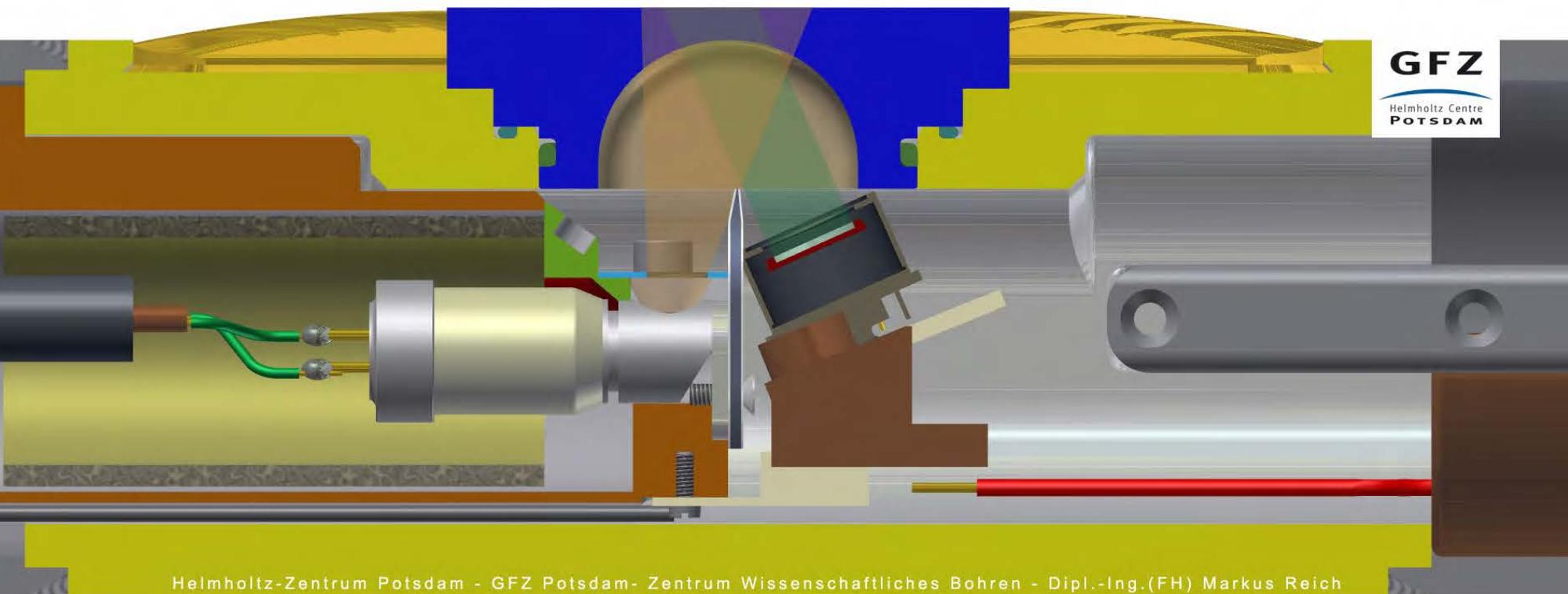
- Probe must be tight, heat resistant and transparent for low energy X-rays
  - Requirements:
    - Thin window
    - Low Z window material
    - Pressure resistant
    - Temperature resistant
  - Solution:
    - High sensor sensitivity (10 Mio cps)
    - High X-ray intensity

# Borehole Probe



# Borehole Probe

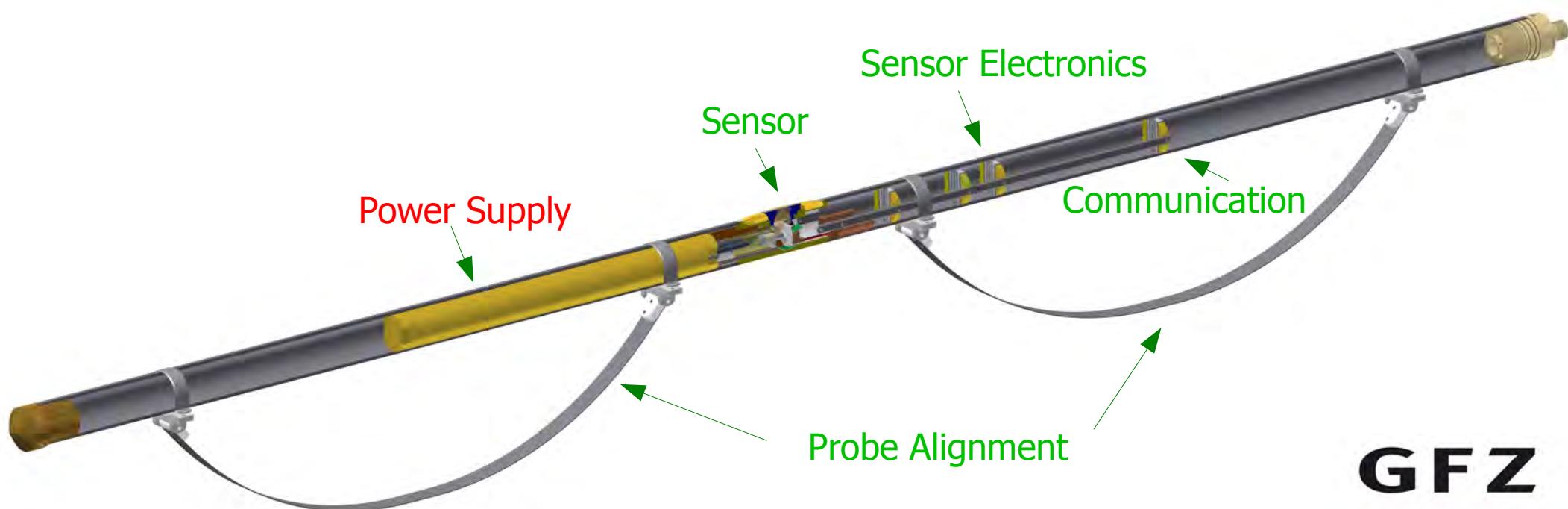
- Sensor Design



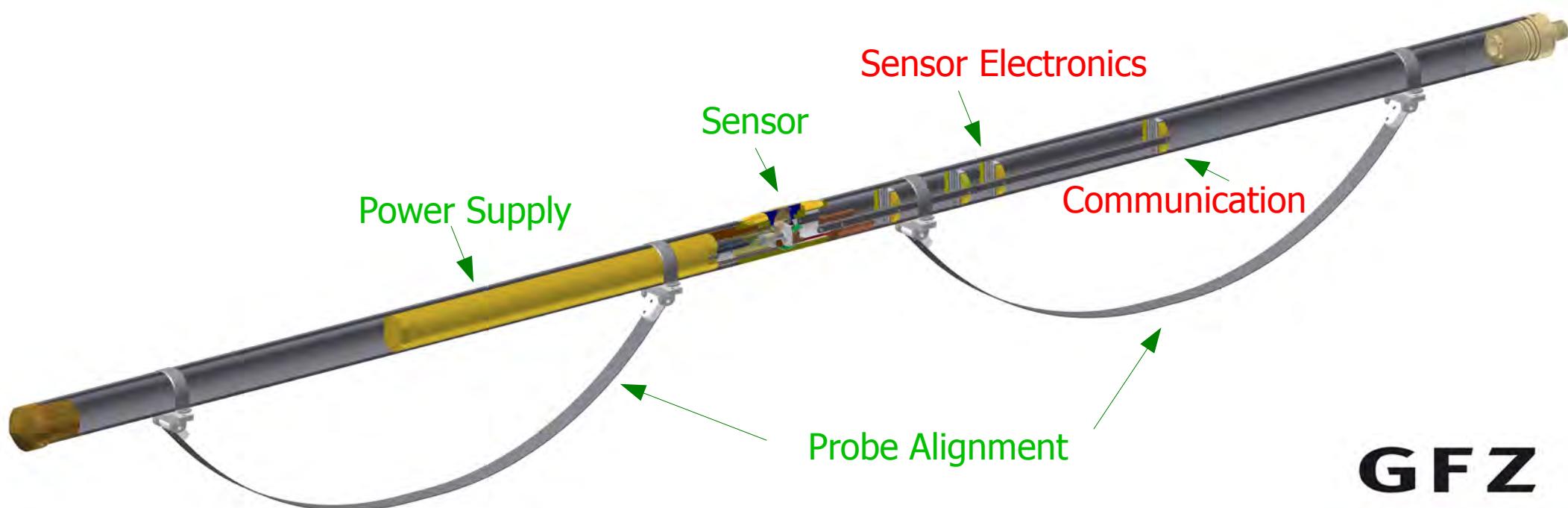
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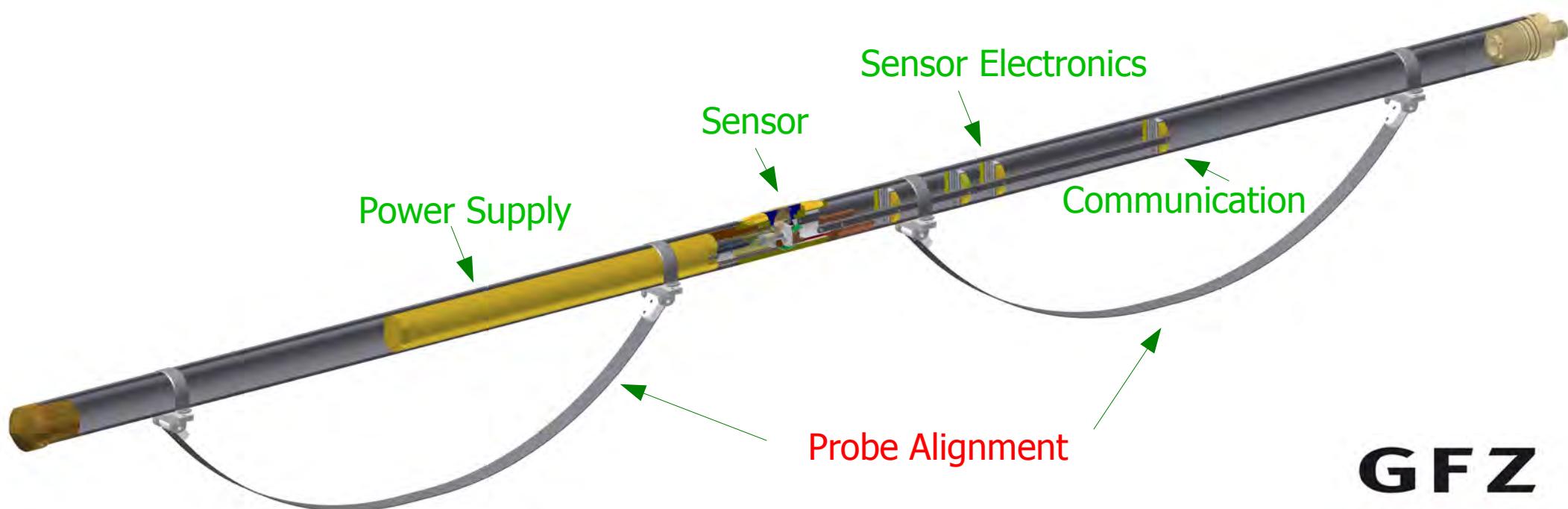
# Borehole Probe



# Borehole Probe



# Borehole Probe



# XRF Borehole Probe

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# XRF Borehole Probe

Thank you for your attention !

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