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Subsurface Icecraft

Development and Testing of a Maneuverable Subsurface Probe That Can Navigate Autonomously Through Deep Ice

9th International Planetary Probe Workshop
Toulouse, France, 18th – 22nd June 2012

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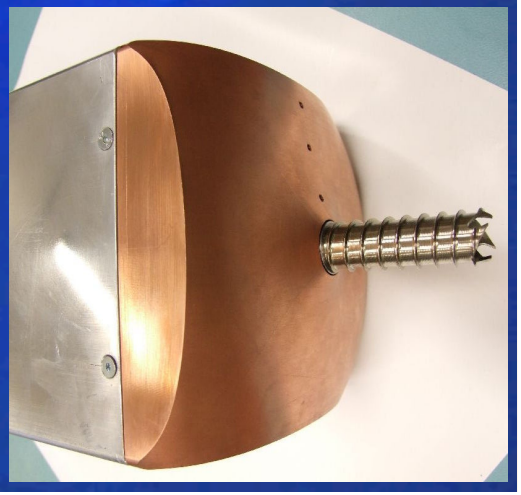
IceMole
Principle of Operations

IceMole
Principle of Operations

IceMole
Principle of Operations

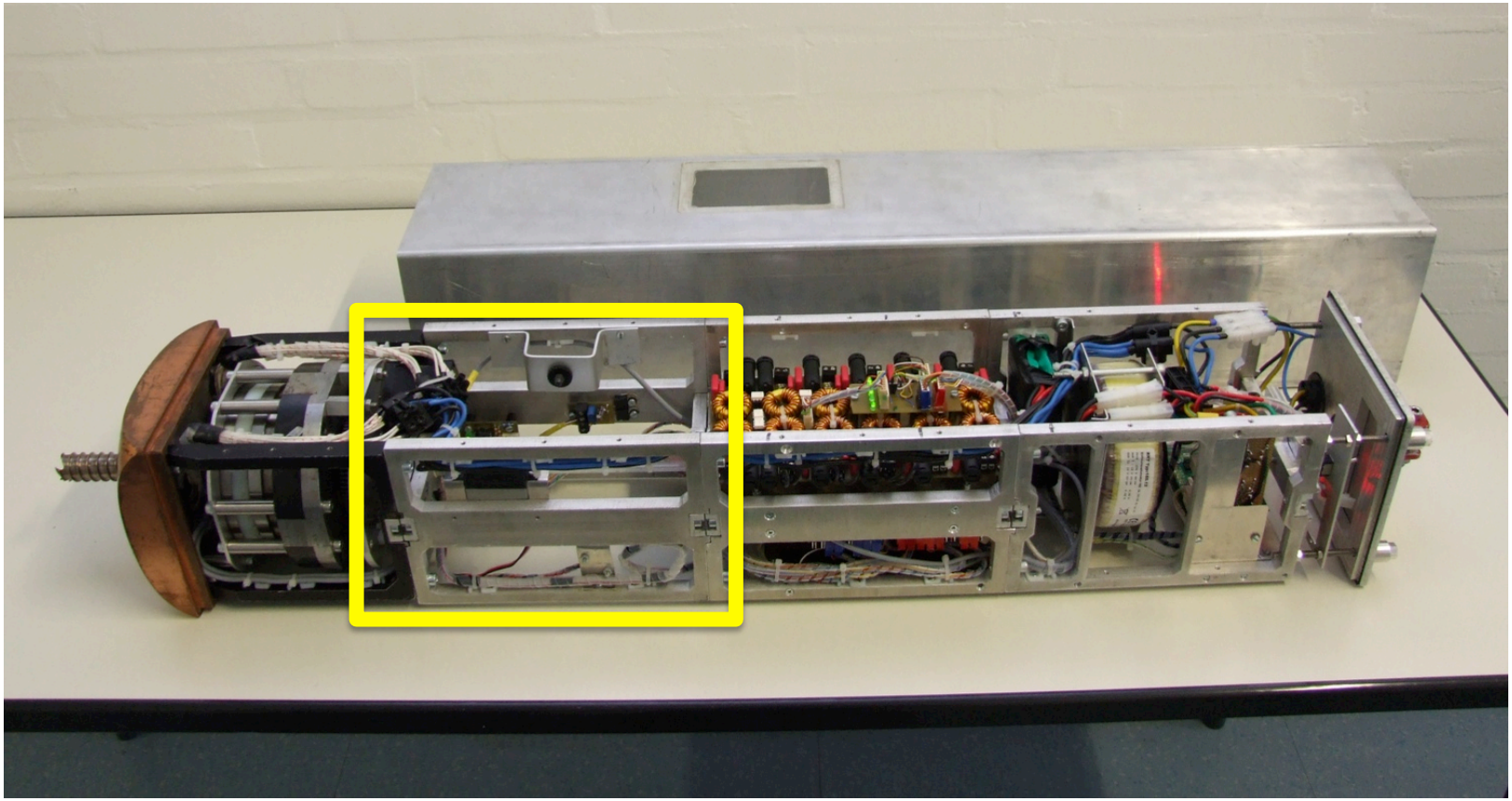
> Forward motion with combined melting head and ice screw
> Maneuverability in ice by differential heating of the melting head



Like a mole, the IceMole is able to "dig" horizontally and even vertically upwards

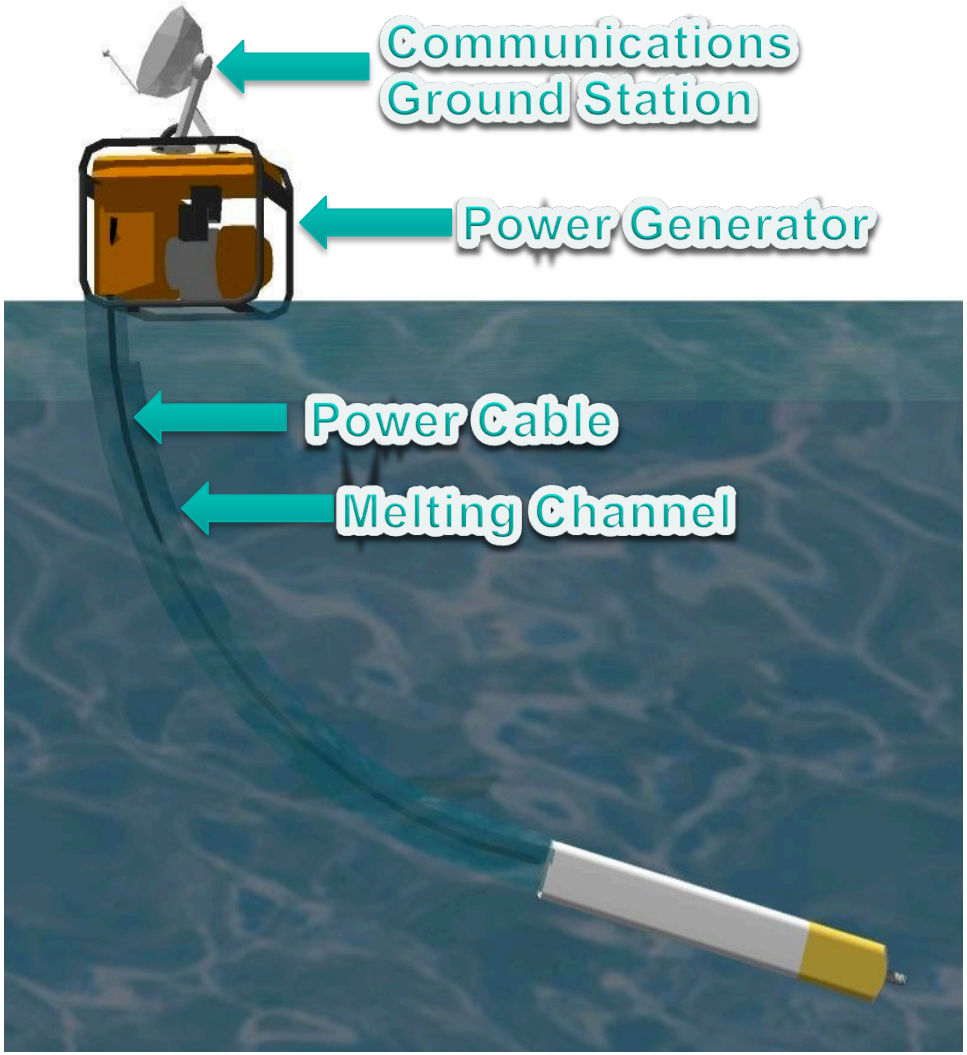
IceMole
Interior View

> Variety of instrumentation options (quadratic instrument bay, 14 cm x 14 cm cross section, length tbd)



IceMole
Operations Concept

- Power supply with generator
- Power cable is coiled within the IceMole (it may freeze behind the probe)
- Powerline-modem transmits data between the IceMole and the ground station via the power cable
- Ground station establishes communications with the operations team via satellite/ internet



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
Field Experiments on the Morteratsch Glacier (2010)

IceMole
Field Experiments | Material Transport

Morteratsch Glacier, Switzerland

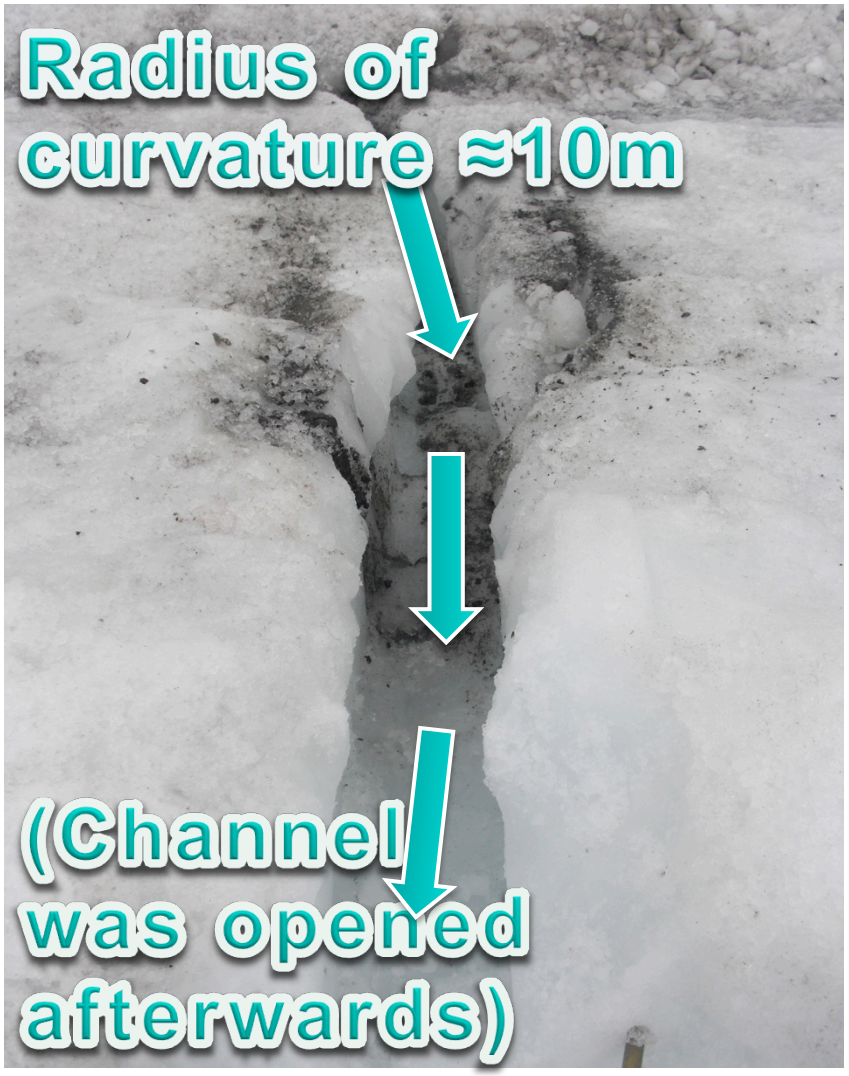
IceMole
Field Experiments | Field Camp

IceMole
Field Experiments | Field Camp

IceMole
Field Experiments | Channel #1

IceMole
Field Experiments | Channel #2

IceMole
Field Experiments | Channel #3



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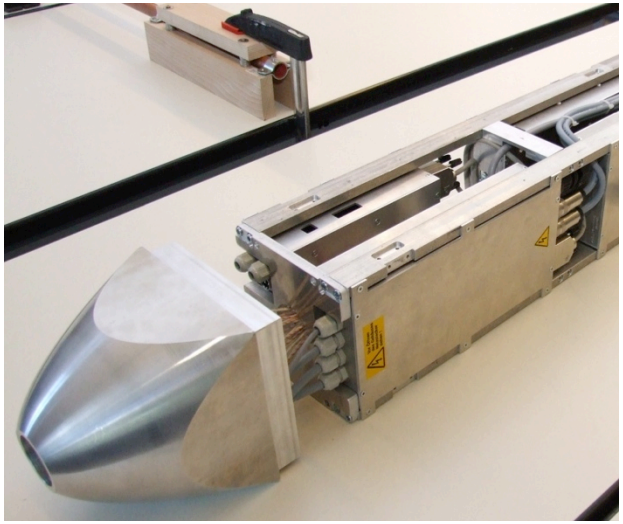
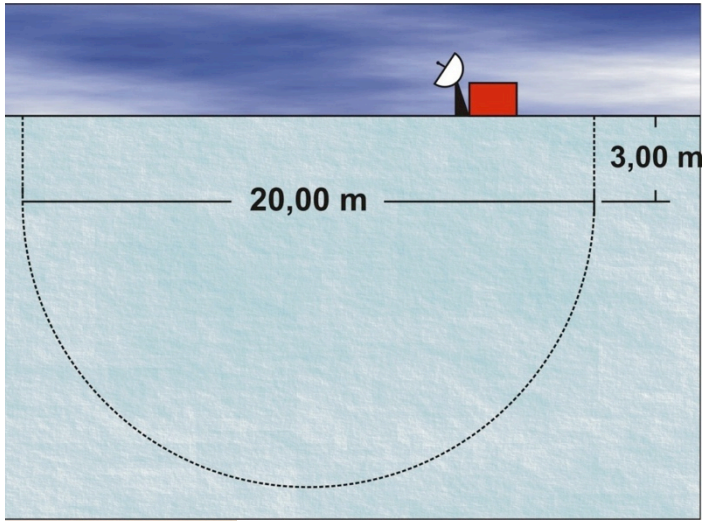
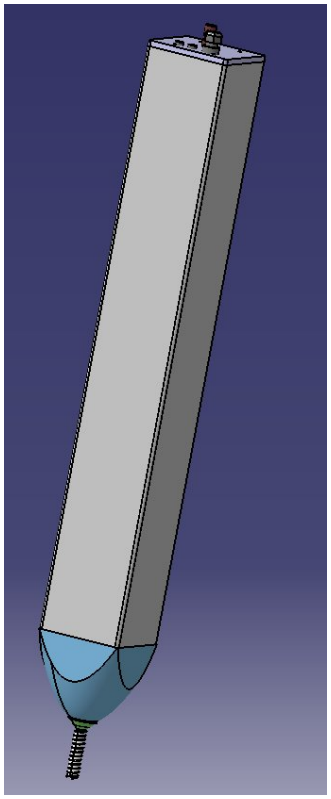
IceMole2
Mission Objectives for Field Tests in September 2012

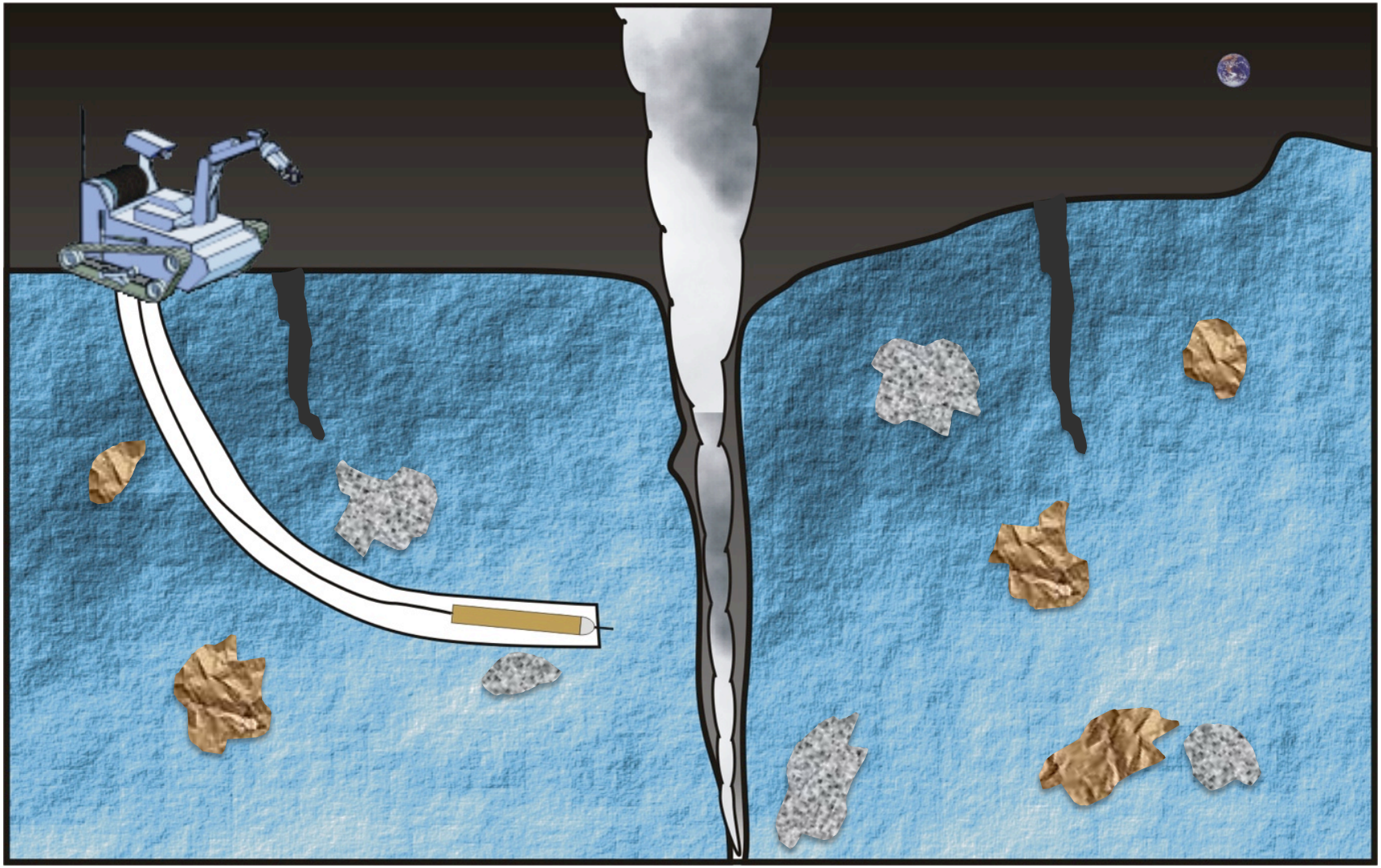
- Demonstrate the recoverability of IceMole and payloads by digging a “vertical U”
- Location: Hofsjökull, Iceland, Sep 2012
- Distance: ≈ 40 m
- Melting velocity: ≈ 1 m/h
- Mass: ≈ 30 kg





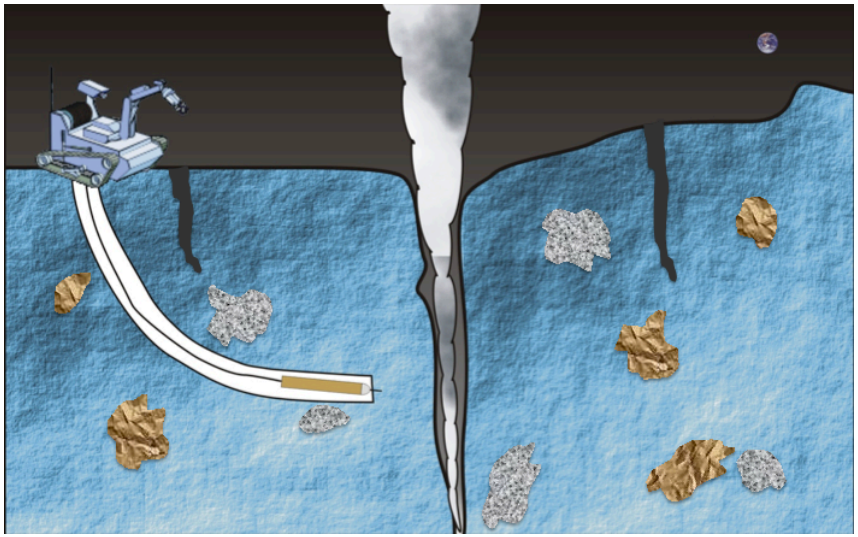


Enceladus Explorer (EnEx)
Mission Scenario



Enceladus Explorer (EnEx)
Mission Objective

"Development of an Autonomous Steerable Subsurface Ice Probe to Demonstrate Autonomous Navigation in Deep Ice"
(not yet in space)



Enceladus Explorer Collaboration:

> **Prof. Dr. Bernd Dachwald** (PI) and Team
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FH Aachen University of Applied Sciences

> **Prof. Dr. Bernd Eissfeller** and Team
Prof. Dr. Roger Förstner and Team
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> **Prof. Dr. Christopher Wiebusch** and Team
RWTH Aachen University

> **Prof. Dr. Klaus Helbing** and Team
Bergische Univ. Wuppertal

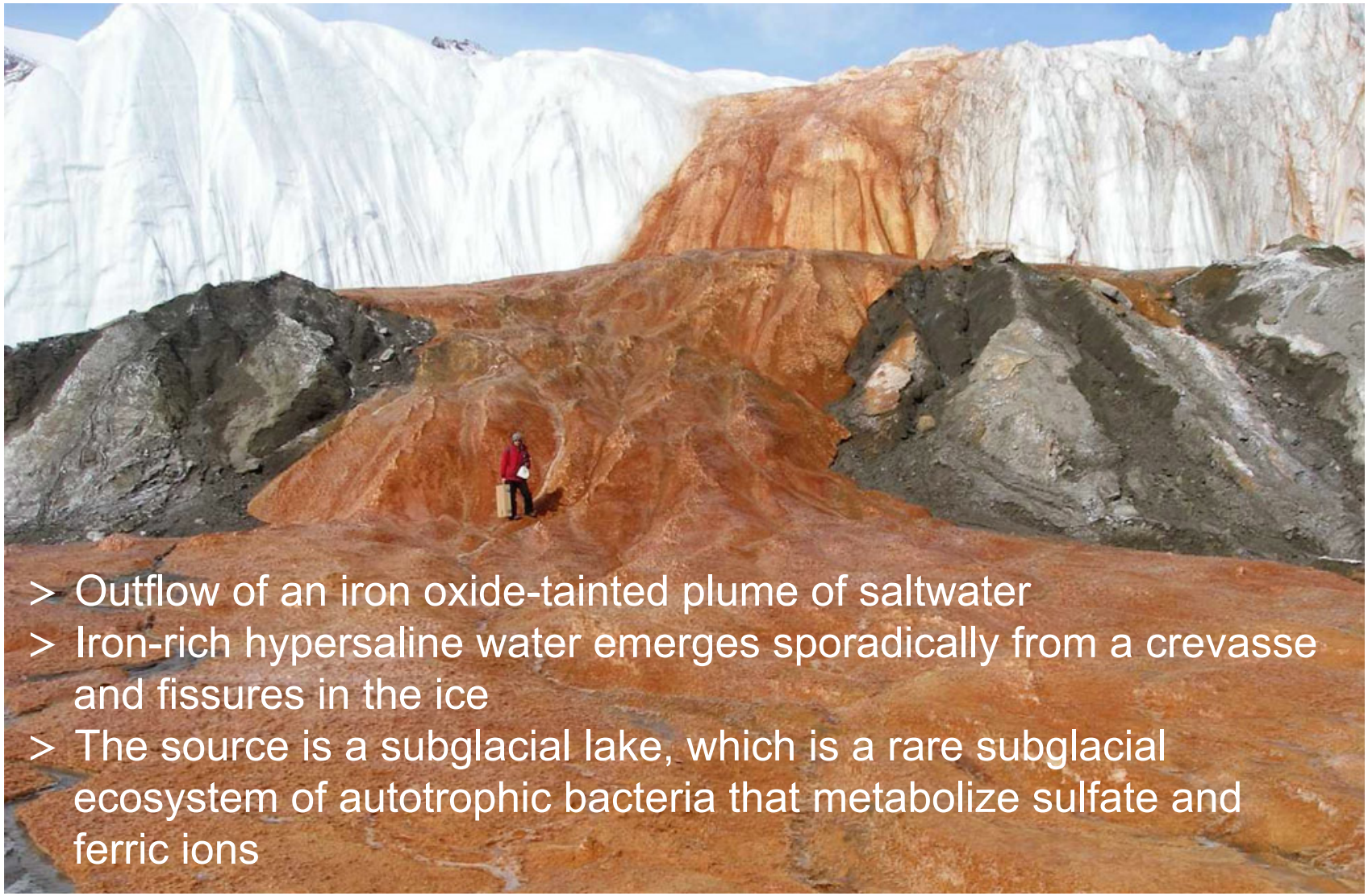
The project Enceladus Explorer is based on an idea and initiative of the DLR space management.

Gefördert durch:
Bundesministerium für Wirtschaft und Technologie
aufgrund eines Beschlusses des Deutschen Bundestages

Enceladus Explorer (EnEx)
Navigation Solution

- Inertial navigation to measure the attitude and calculate the position in the ice
- Ultrasound sensor head to detect the crevasse and to detect obstacles in the ice
- Acoustic pingers on the surface to measure the position in the ice
- Intelligent multi-sensor fusion to generate a scenario for the operator from the raw data and for autonomous operation
- Maneuverability and trajectory optimization w.r.t. resources, time, and risk

Blood Falls, Antarctica | Enceladus on Earth
A Unique Subglacial Aquatic Ecosystem



> Outflow of an iron oxide-tainted plume of saltwater
> Iron-rich hypersaline water emerges sporadically from a crevasse and fissures in the ice
> The source is a subglacial lake, which is a rare subglacial ecosystem of autotrophic bacteria that metabolize sulfate and ferric ions

Blood Falls, Antarctica | Enceladus on Earth

Close-Up of the Blood Falls Crevasse

Blood Falls, Antarctica | Enceladus on Earth

Close-Up of the Blood Falls Crevasse

MIDGE
US Team

MIDGE: Minimally Invasive Direct Glacial Exploration

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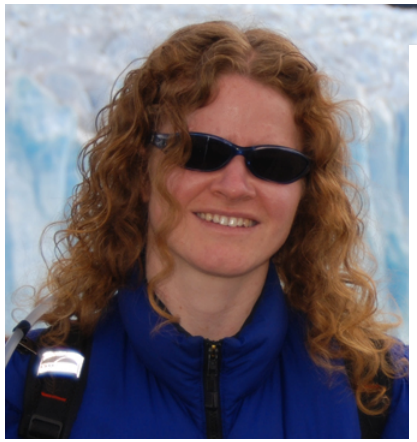

MIDGE & EnEx
Mission Objective

MIDGE: Minimally Invasive Direct Glacial Exploration

"Clean sample return of subglacial water from a crevasse for life detection and analysis"

- 3 melting channels are planned
- They intersect the crevasse ≈ 40 m below the surface
- They will have a length of ≈ 60 – 100 m
- Field test of the EnEx probe at Blood Falls will be in 2014
- Before, two field tests in Alaska and Antarctica will be in 2013
- EnEx is already funded

MarsMole
Preparing the IceMole for Extraterrestrial Applications

- Traditional melting probes have difficulties with melting under low-pressure conditions (poor heat transfer at the melting head)
- MarsMole is a smaller IceMole with 6 cm x 6 cm cross section and ≈ 4 kg
- MarsMole will be tested by the end of 2012 under simulated Mars conditions (pressure, temperature) to demonstrate the feasibility of the IceMole concept

Thank you for your attention!

Questions?

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