Erkundung und Kartographierung des Jupitermondes Europa – Vollautonome Langzeitmissionen mit Unterwasserfahrzeugen

Gefördert vom BMWi (Kennziffern 50NA1217 und 50NA1704)

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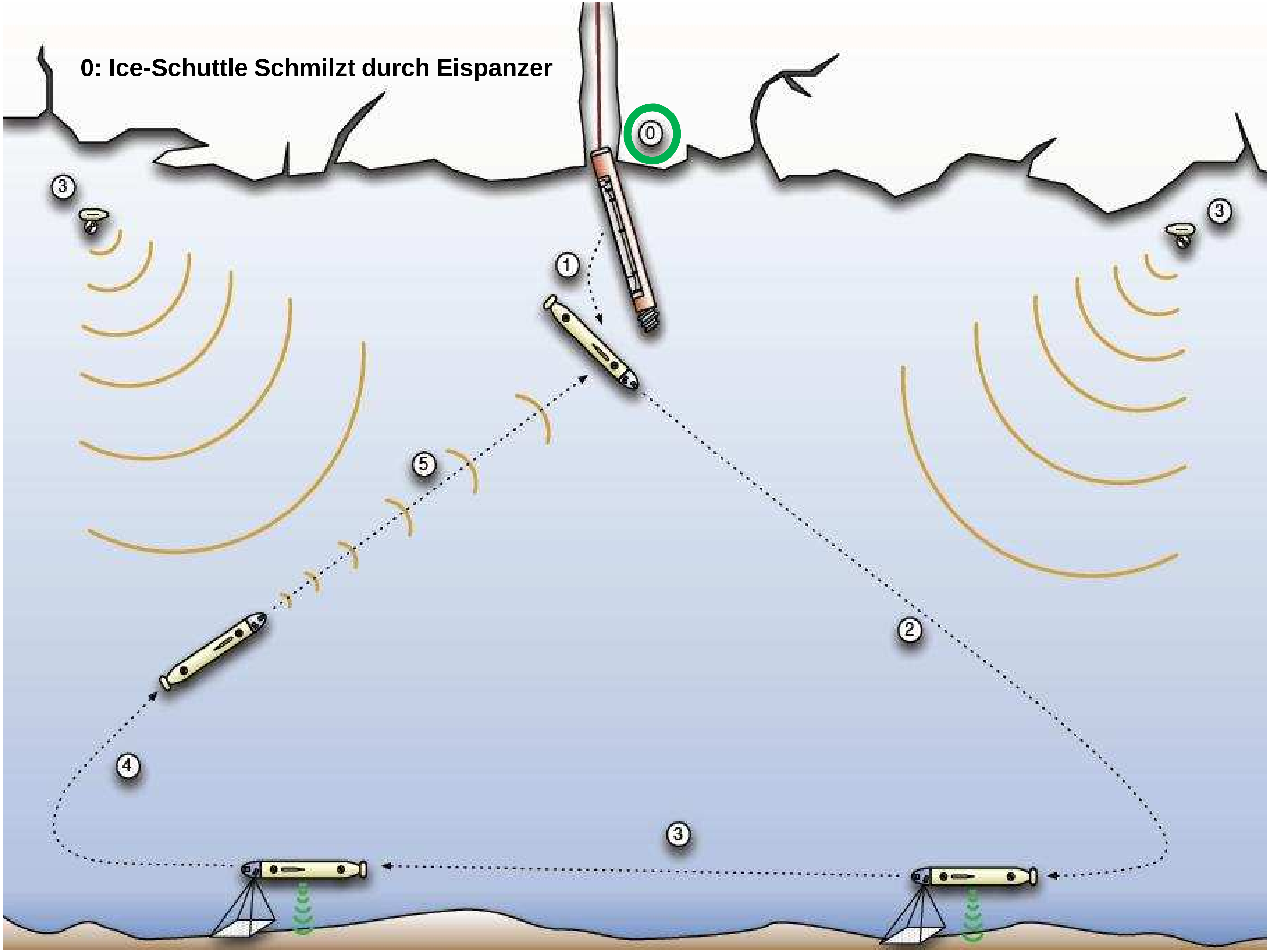
Universität Bremen

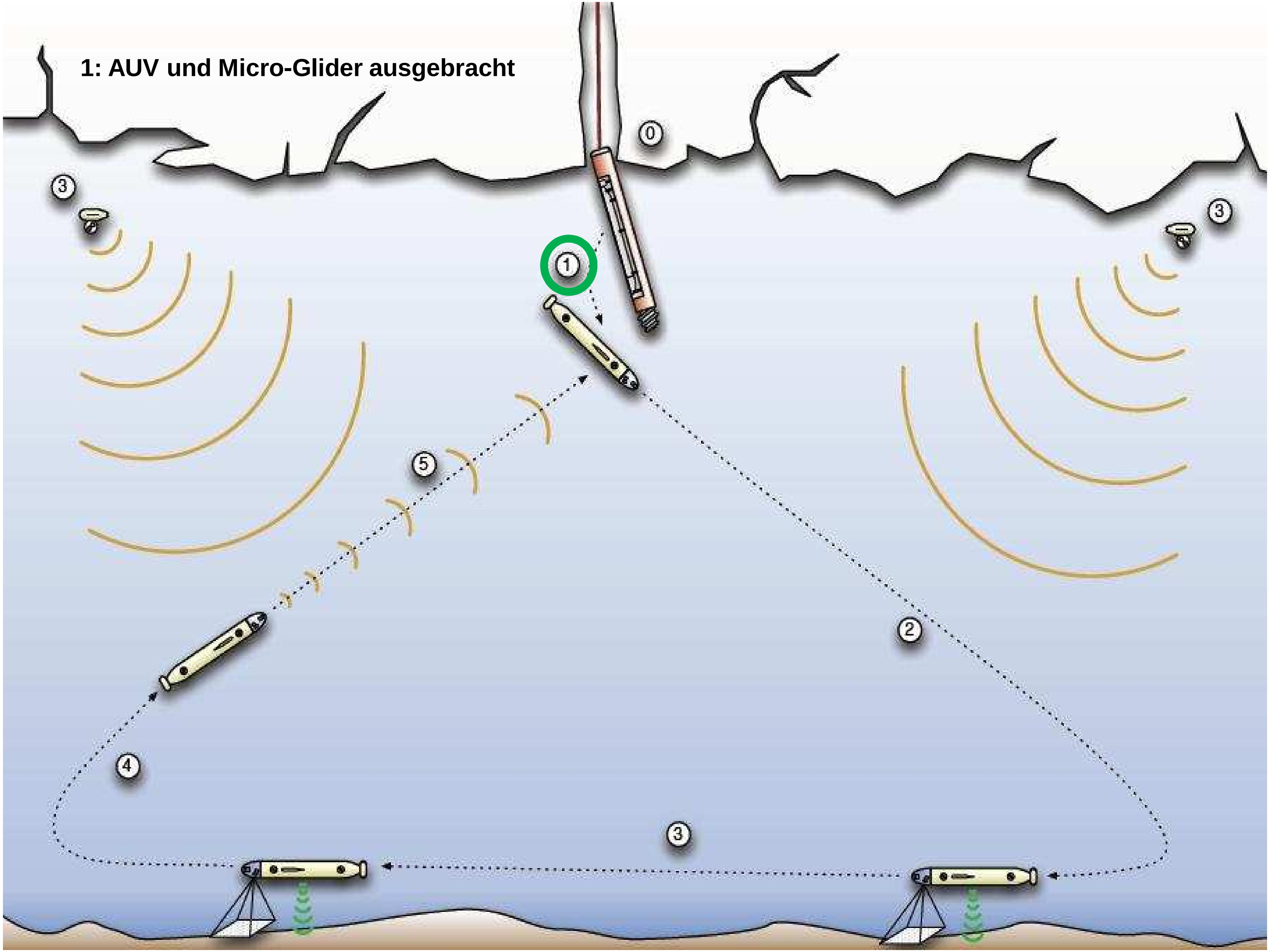
Projektziele EurEx

- Vorbereitung einer Mission zum Jupitermond Europa
  → **Missionskonzept**
- Machbarkeitsnachweis einer möglichen Mission in einem terrestrischen Szenario
- **Sichere Navigation** unter Eis
  - Langzeitautonomie
  - Autonomes Eisbohren mit Nutzlast
  - Aufbau einer Navigationsinfrastruktur unter der Eisdecke
- Aufbau eines funktionsfähigen **Demonstrationssystems** aus AUV und Eisbohrer

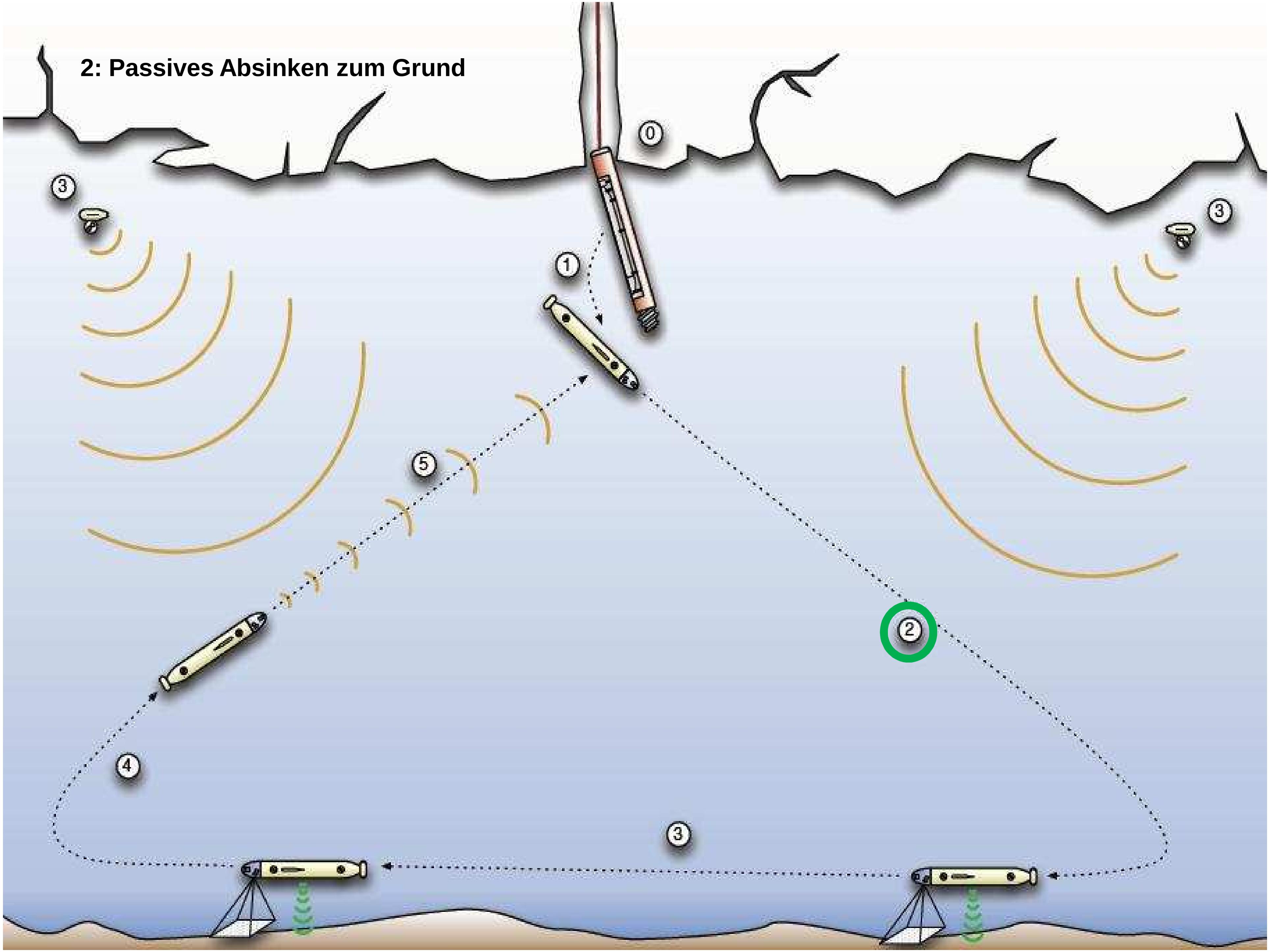
0: Ice-Schuttle Schmilzt durch Eispanzer



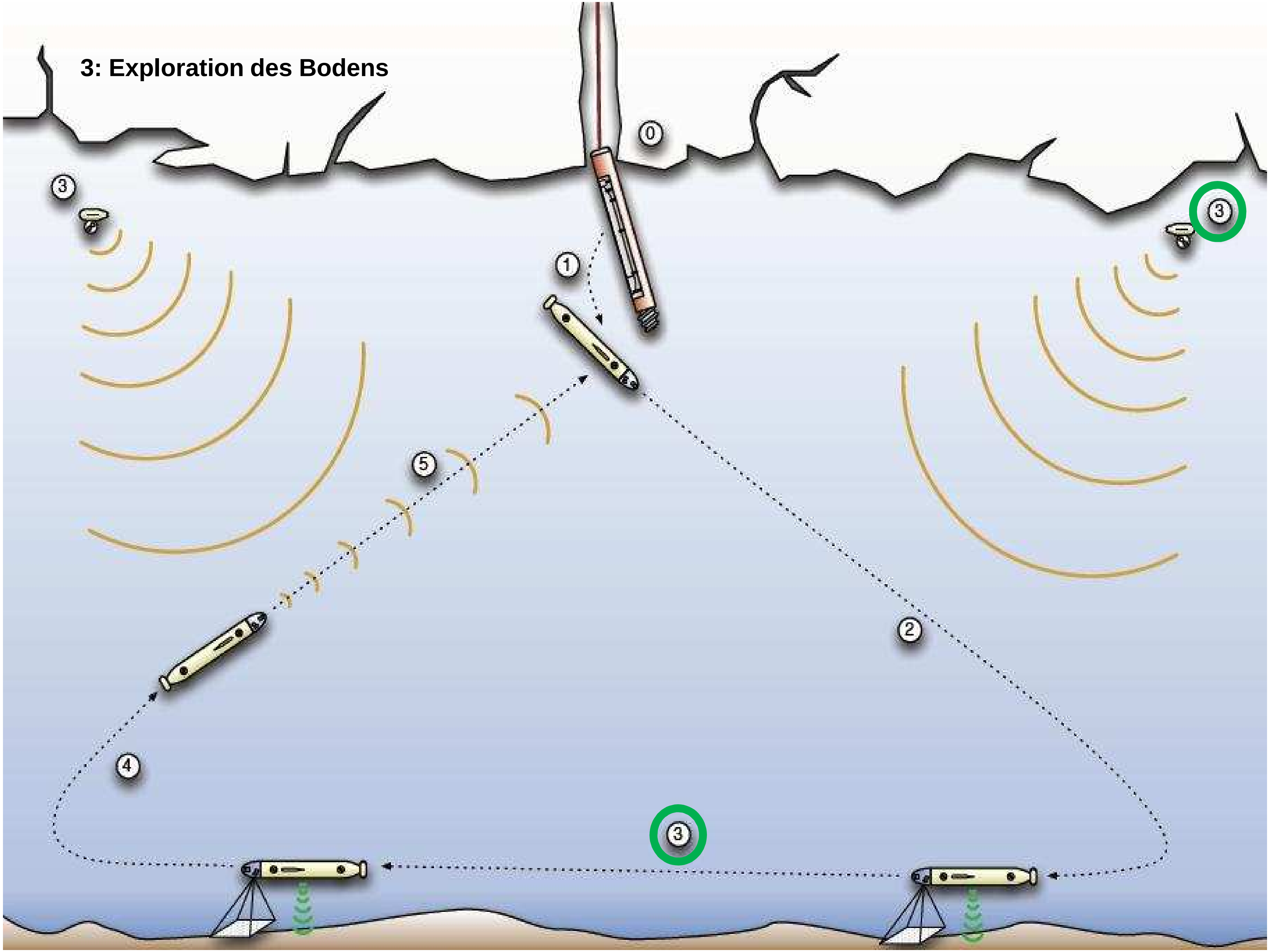
1: AUV und Micro-Glider ausgebracht



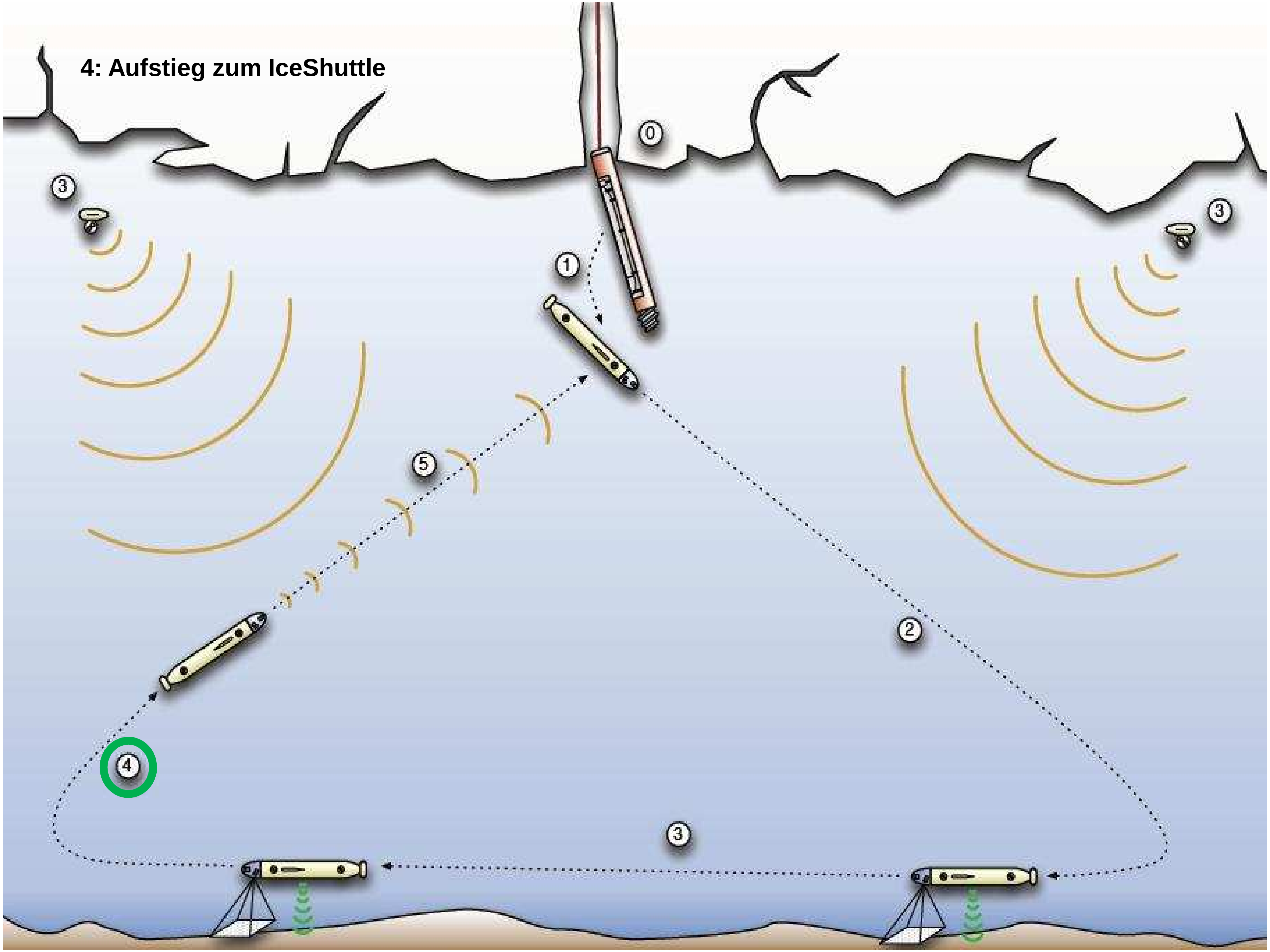
2: Passives Absinken zum Grund



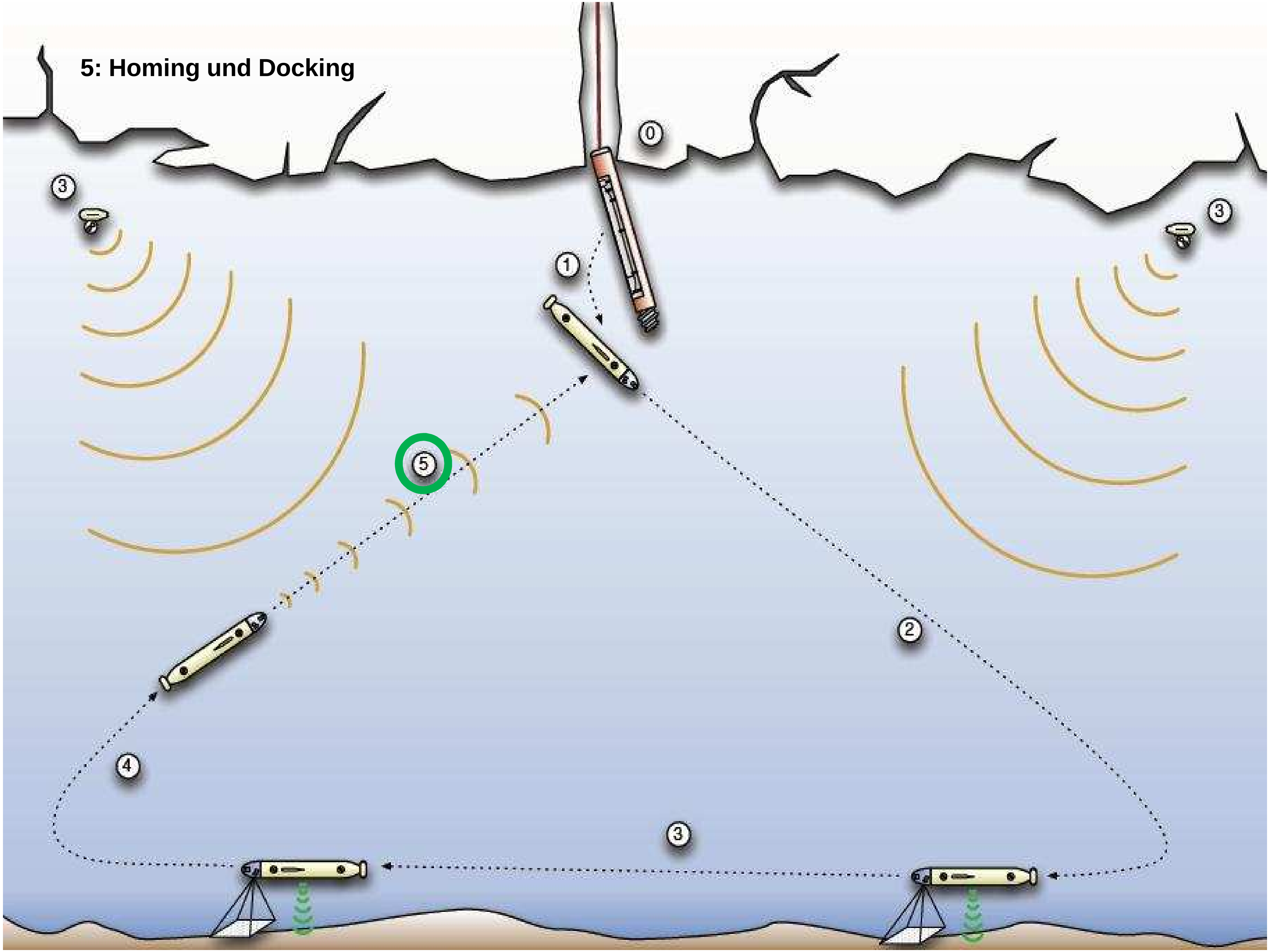
3: Exploration des Bodens



4: Aufstieg zum IceShuttle

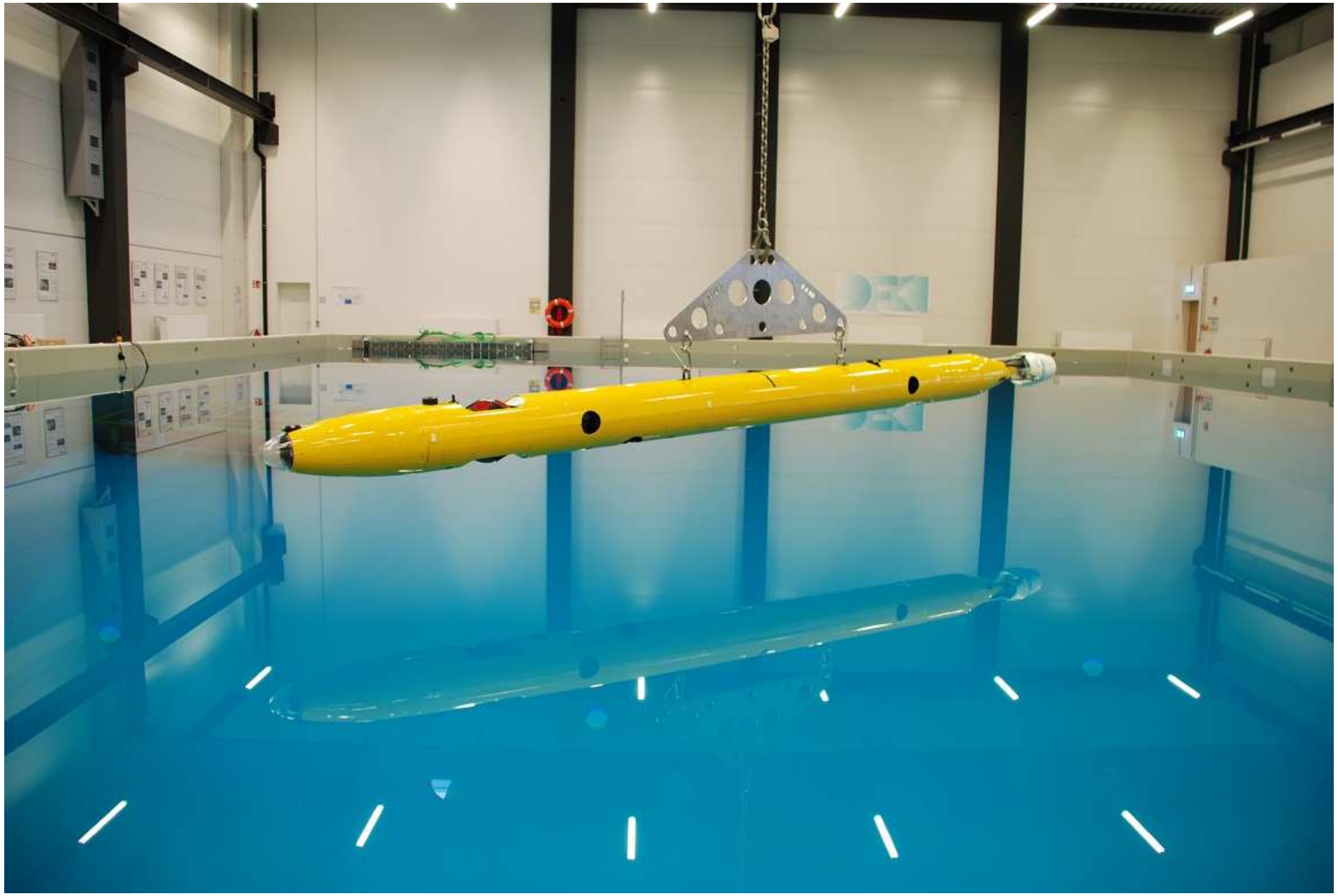


5: Homing und Docking



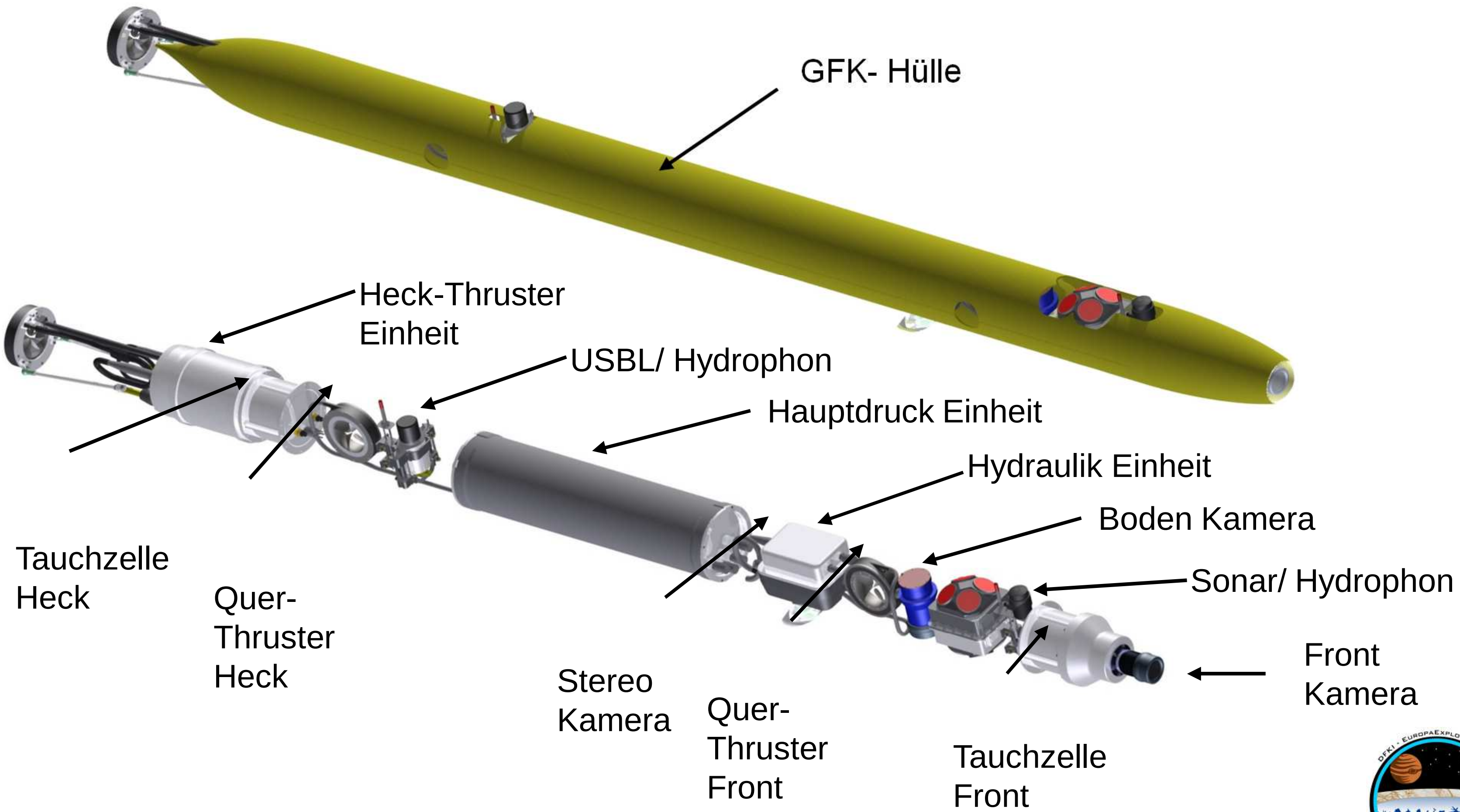
AUV

Exploration-AUV: Leng



Explorations-AUV: Leng

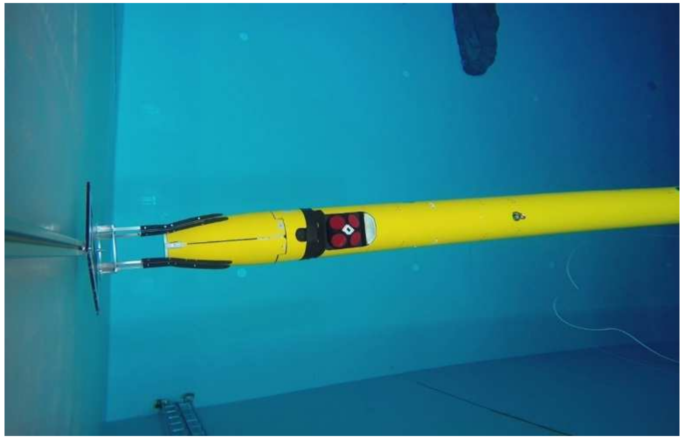
Funktionseinheiten AUV:



Explorations-AUV: Leng

AUV Primär Spezifikationen:

- *Abmaße/ Gewicht:*
  4000 x Ø 210mm/ ca. 90kg
- *Vortrieb:*
  Enitec Thruster 60N Schub
- *Seitenführung:*
  2x Querthruster je 60N Schub
- *Fahrleistung:*
  ca. 4m/s
- *Betriebszeit:*
  ca. 10Std
- *Tauchtiefe:*
  150m
- *Tarierung /Neutral Tauchzelle:*
  2x 1,35 Liter- 50 ml/sec

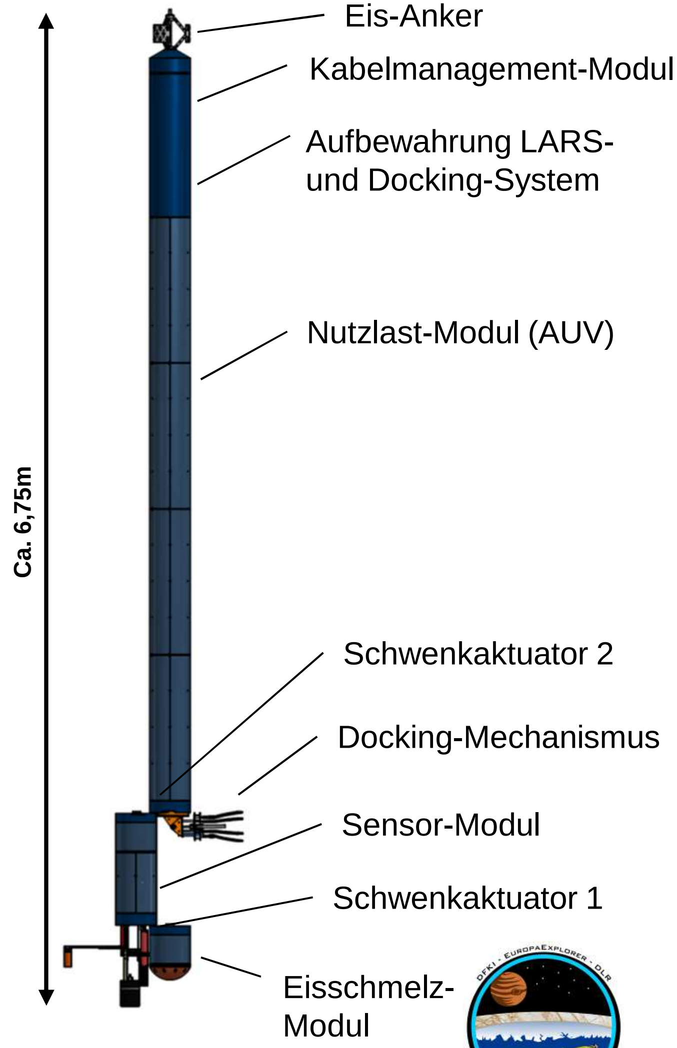


IceShuttle

IceShuttle

- Anforderungen:
  - **Transport** des AUVs durch einen Eispanzer
  - Dauerhaftes Halten der finalen Position
  - **Ausbringen** und starten des AUVs
  - Bereitstellung zusätzliche **Navigations-Systeme** für das AUV (USBL, CTD, akustischer Pinger)
  - **Docking-Schnittstelle** AUV
  - Aufnehmen und **reintegrieren** des AUV ins Transport-Modul (Anforderung: terrestr. Szenario)
  - **Größenbeschränkung** (Abhängigkeit zwischen benötigter Schmelzleistung und Baugröße)
  - **Entfaltung (kompaktes System)**

- Hauptanforderungen:
  - *Integration eines hochautonomen AUVs in eine Eisschmelzsonde*
  - *Demonstration des vollen Missionsumfangs*

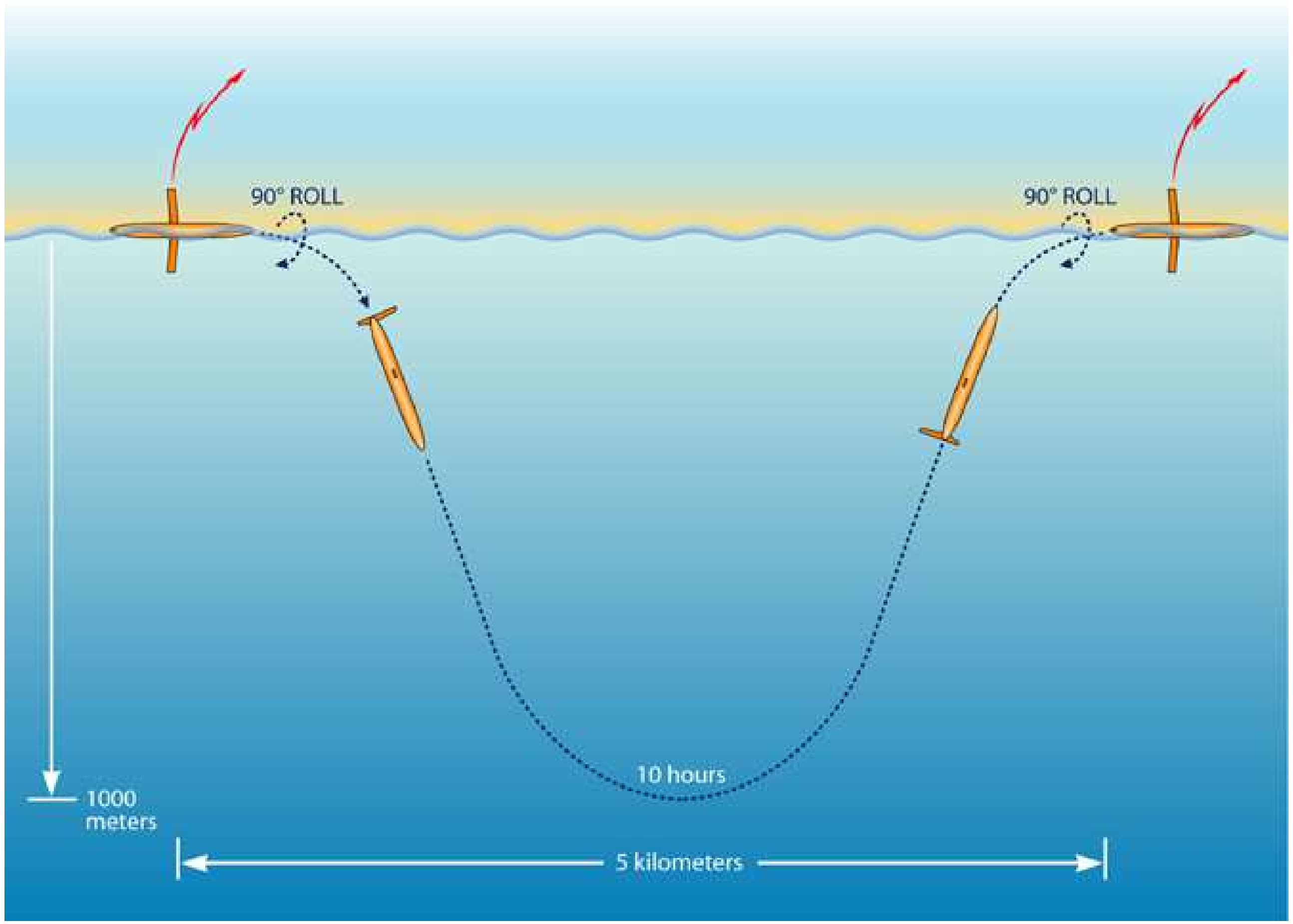


IceShuttle – Finale Integration

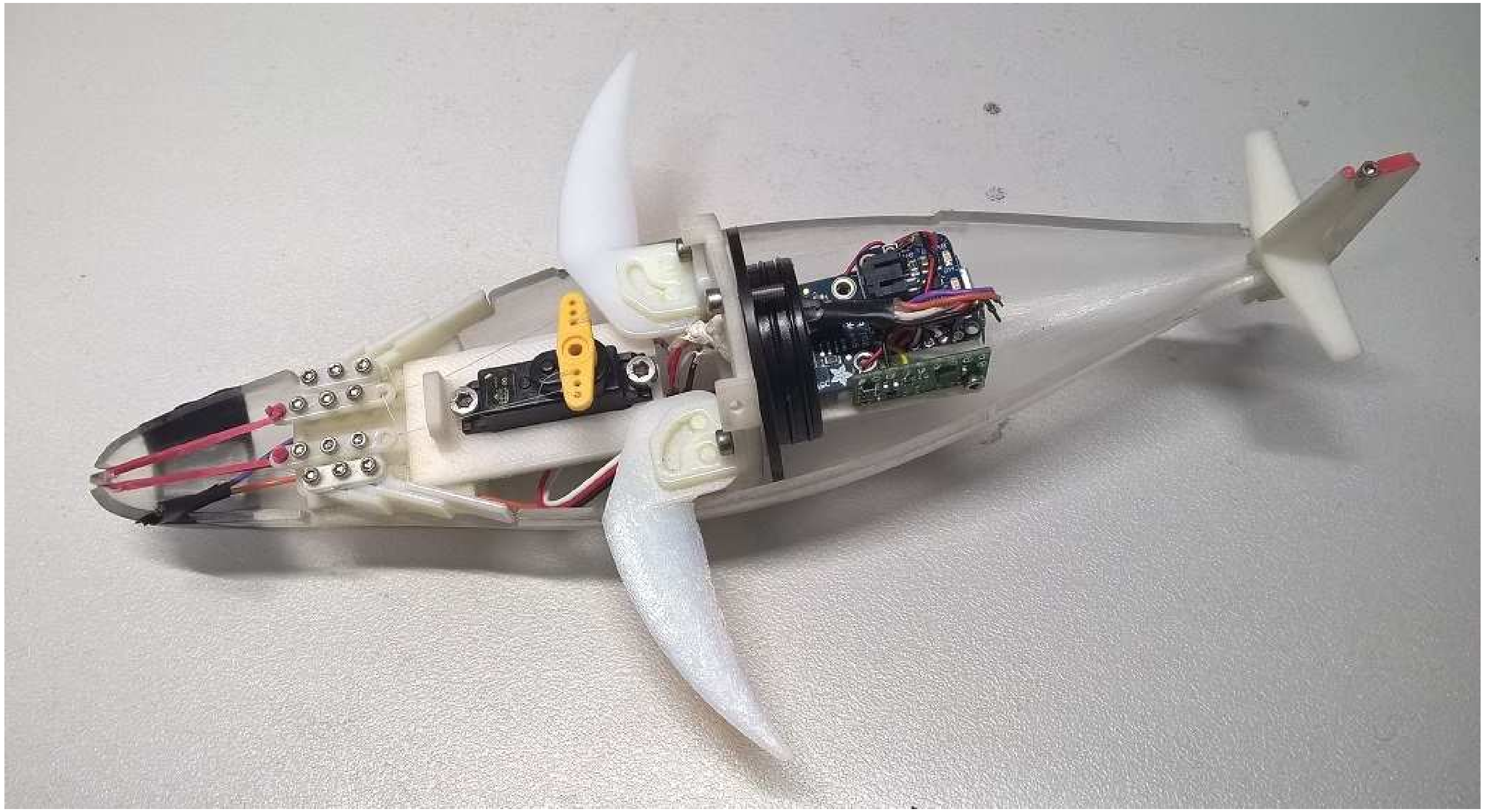
Microglider

(Multi-Beacon Navigation)

Glider: Fortbewegungsprinzip



EurEx-Microglider



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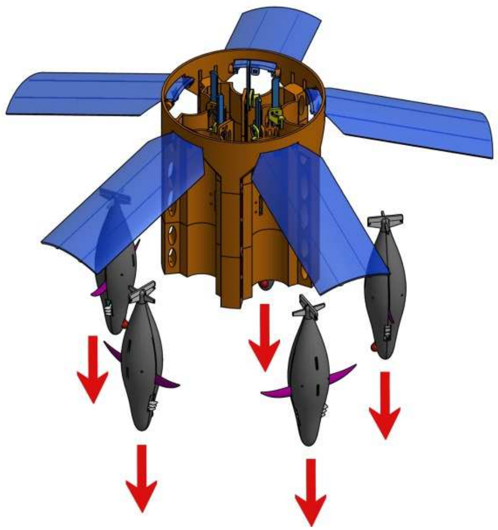
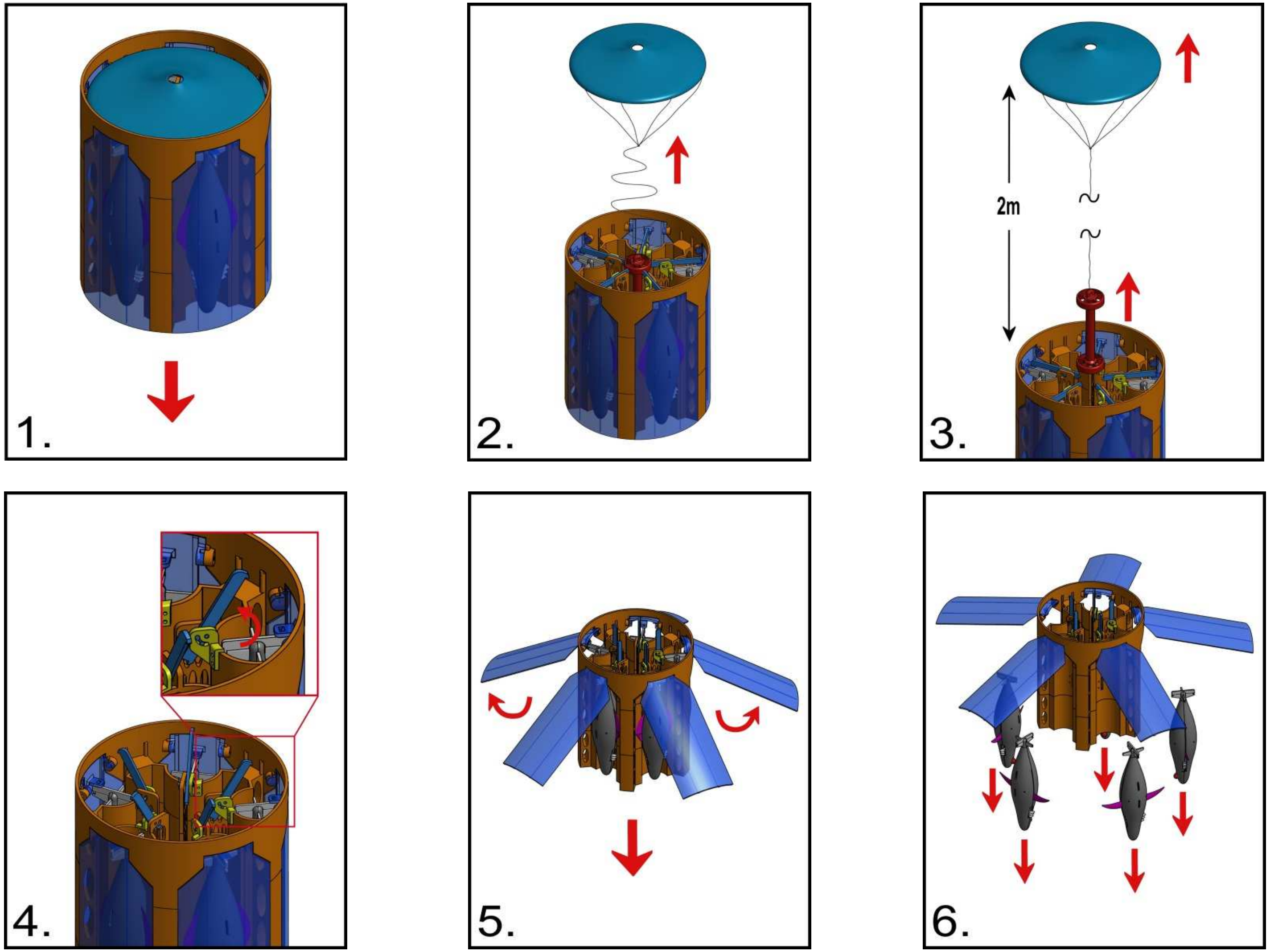
Launch-System Glider

- Ausbringen und Starten der Glider
- Vorrichtung für die geordnete und sichere Lagerung im Nutzlastmodul
- 5 Glider gleichzeitig starten
- Timing für das Start der Glider wichtig
- Glider erst starten wenn keine Hindernisse mehr vorhanden sind
- Keine zusätzliche Aktorik notwendig
  → passives System

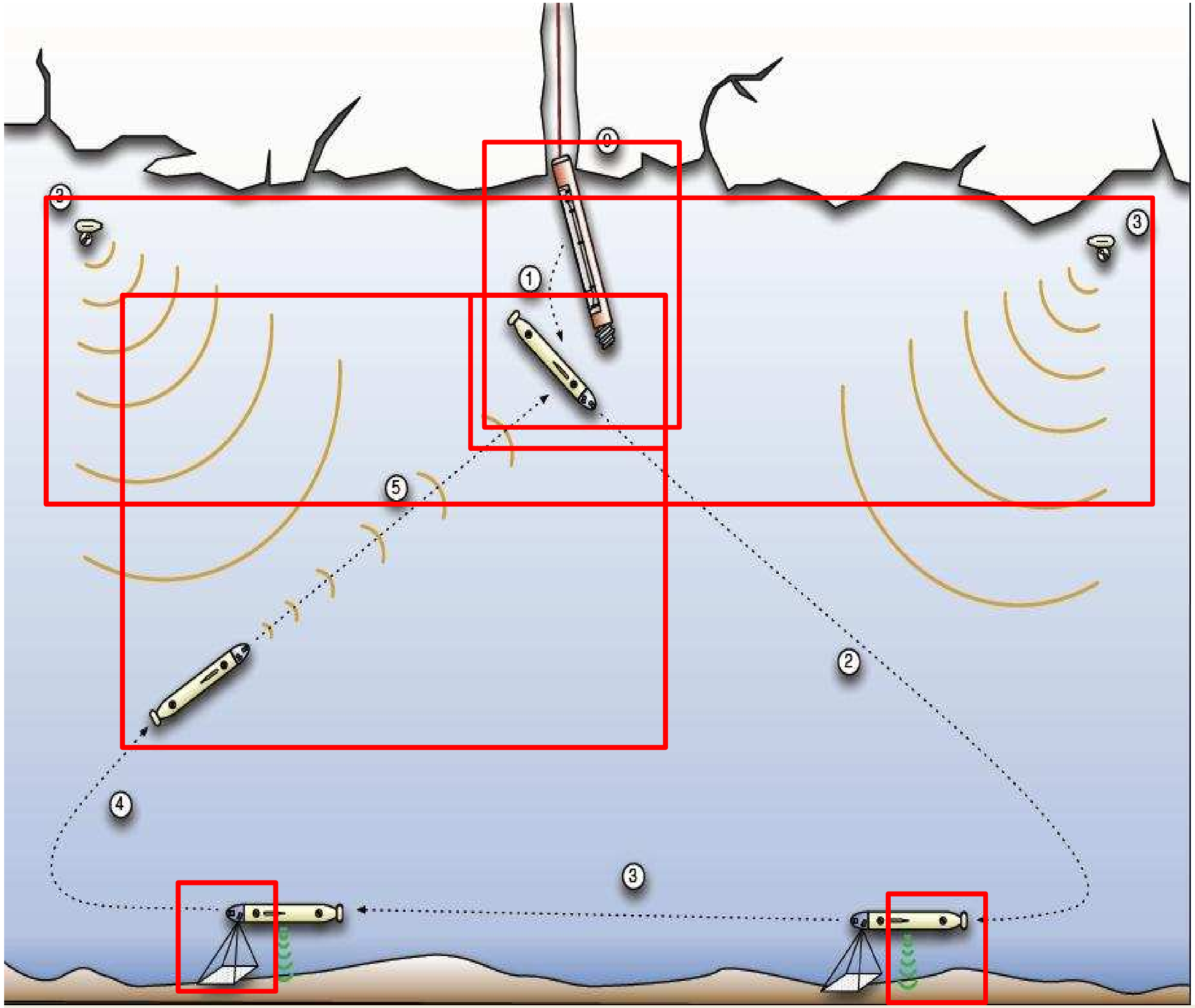


Launch-System Glider



Navigation

Navigationsmodalitäten



- Eisbohrer-relative Navigation
  - Single-Beacon-Navigation
  - Multi-Beacon-Navigation
  - USBL-Homing
  - Docking
- Boden-relative Navigation
  - DVL-Basierte Koppelnavigation
  - Visuelle Navigation

Externes Video

- Vielen Dank!

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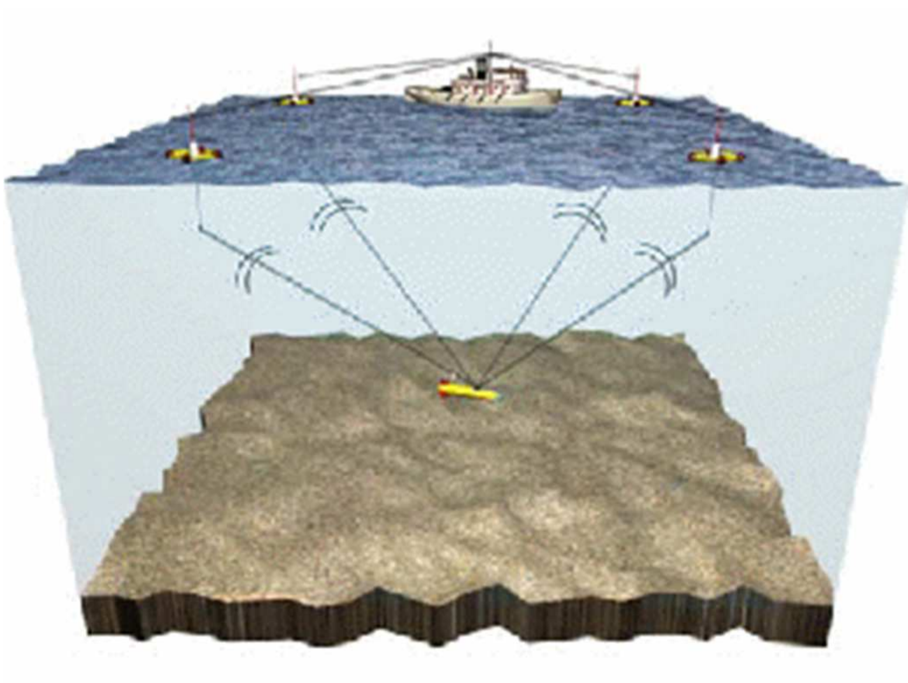
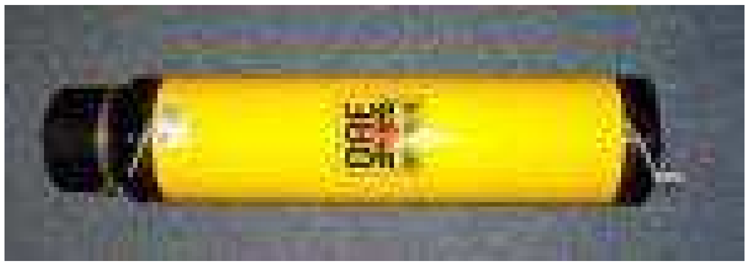
Review of Underwater Navigation Methods I

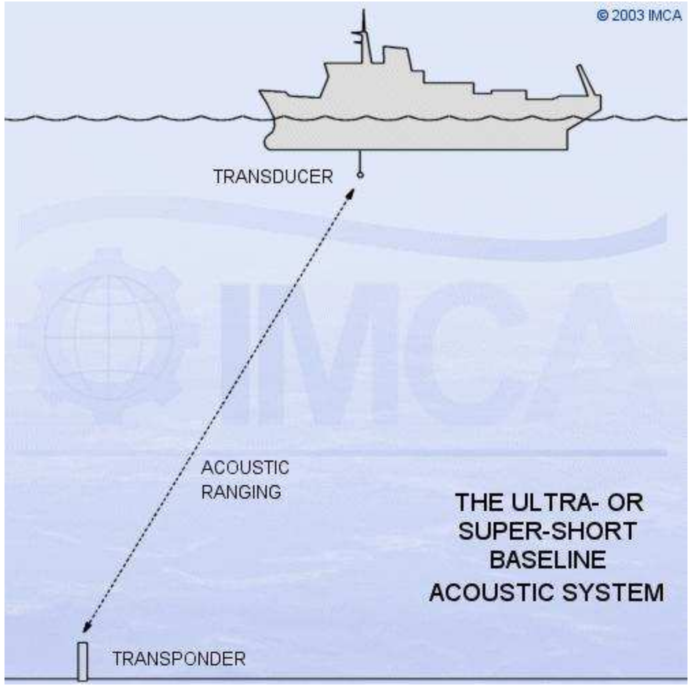
- External Navigation Aids
  - LBL Acoustic System („underwater GPS“):
    - ►Four stationary transponders
    - ►Mobile receiver measures TOF
    - ►Requires good measurement of sound speed in water
    - ►Requires infrastructure
    - ►Requires constant line of sight
    - ►Precision ~20cm, range ~1km





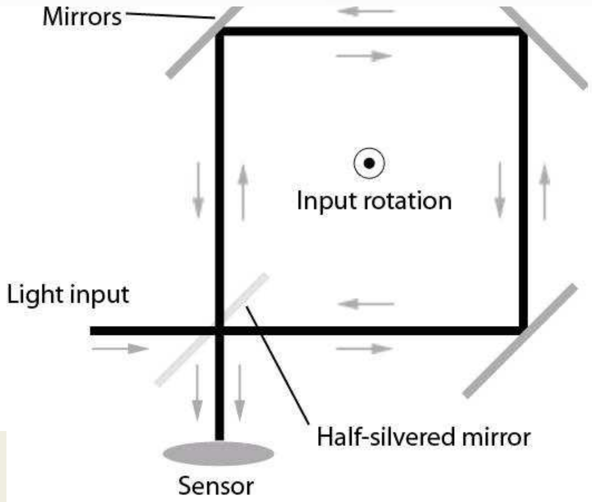
Review of Underwater Navigation Methods II

- External Navigation Aids
  - USBL Acoustic System
    - ►One stationary transponder with three hydrophones
    - ►Measures TOF and phase variance
    - ►calculated distance and heading is acustically send to mobile receiver
    - ►Requires good measurement of sound speed in water
    - ►Requires light infrastructure
    - ►Requires constant line of sight
    - ►Precision range dependant
    - ►Range < 1km



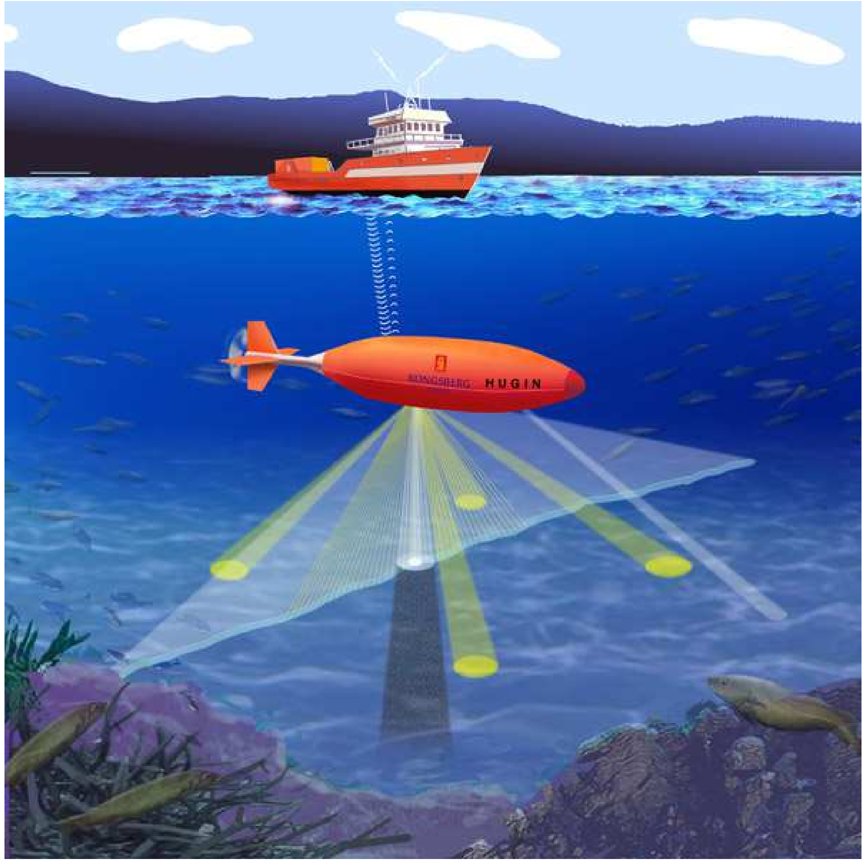
Review of Underwater Navigation Methods III

- Internal Navigation Aids
  - Inertial Navigation System:
    - ►3 gyroscopes, compasses and accelerometers
    - ►Compasses as absolute orientation sensors, gyroscopes and accelerometers as linear/rotary acceleration sensors
    - ►Suffer from sensor drift
    - ►Suffer from magnetic disturbances
    - ►Best systems with FOG as gyroscope, but expensive and heavy
    - ►Performance ~0.2° orientation precision, 1km position (drift per hour)

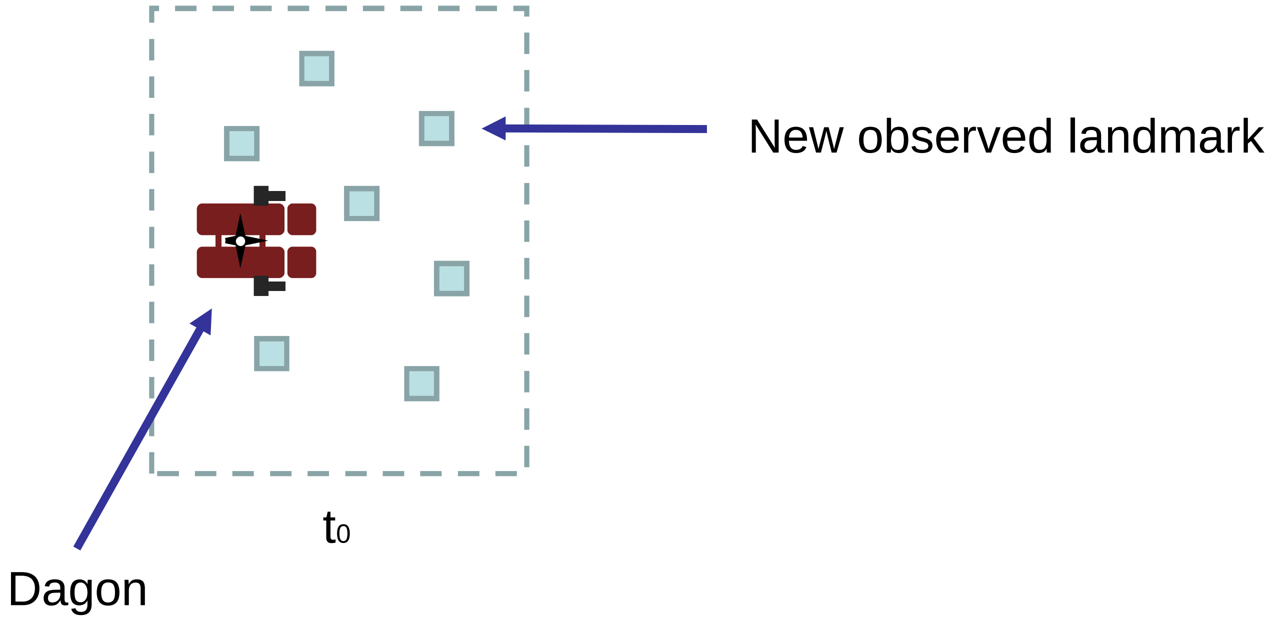


Review of Underwater Navigation Methods IV

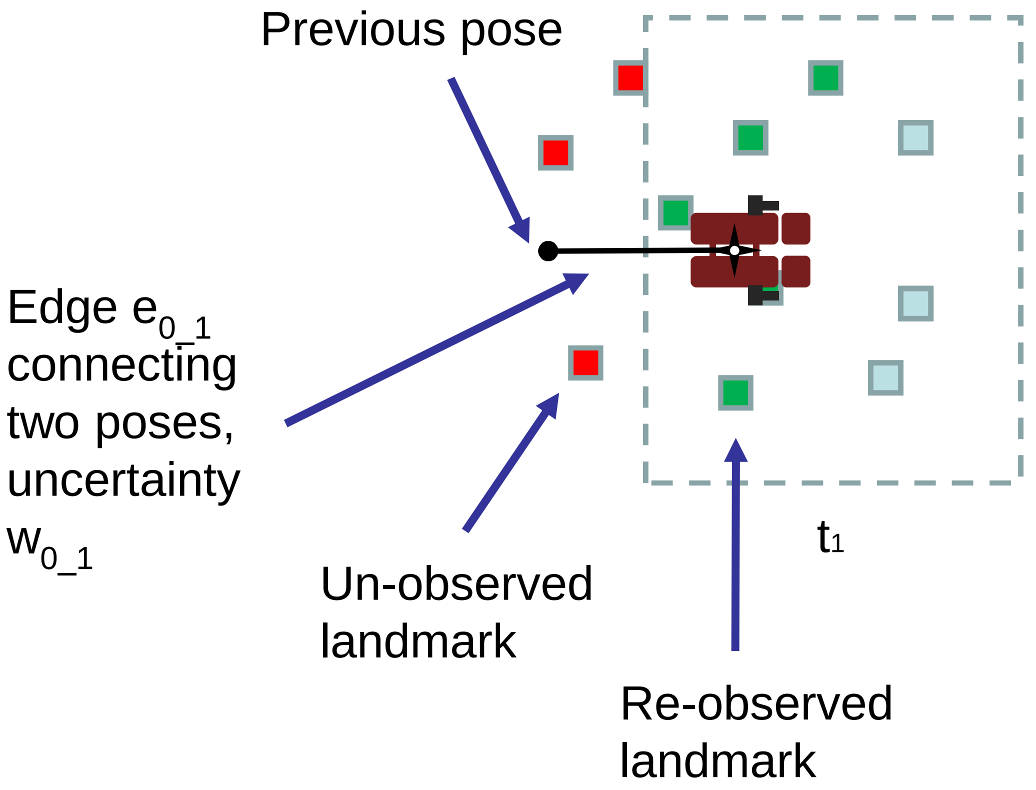
- Internal Navigation Aids
  - DVL Acoustic System (also called ADCP):
    - ►Four independent acoustic beams
    - ►Measures phase shift in signal return
    - ►Calculates speed over ground
    - ►Requires good measurement of sound speed in water
    - ►Requires surface contact (range 1-200m)
    - ►Precision ~0.2cm/s



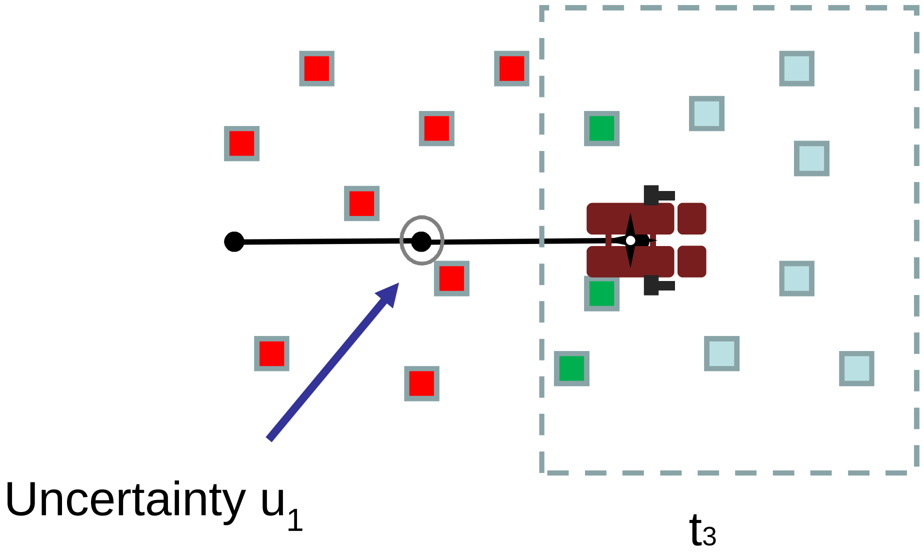
Pose-Based SLAM



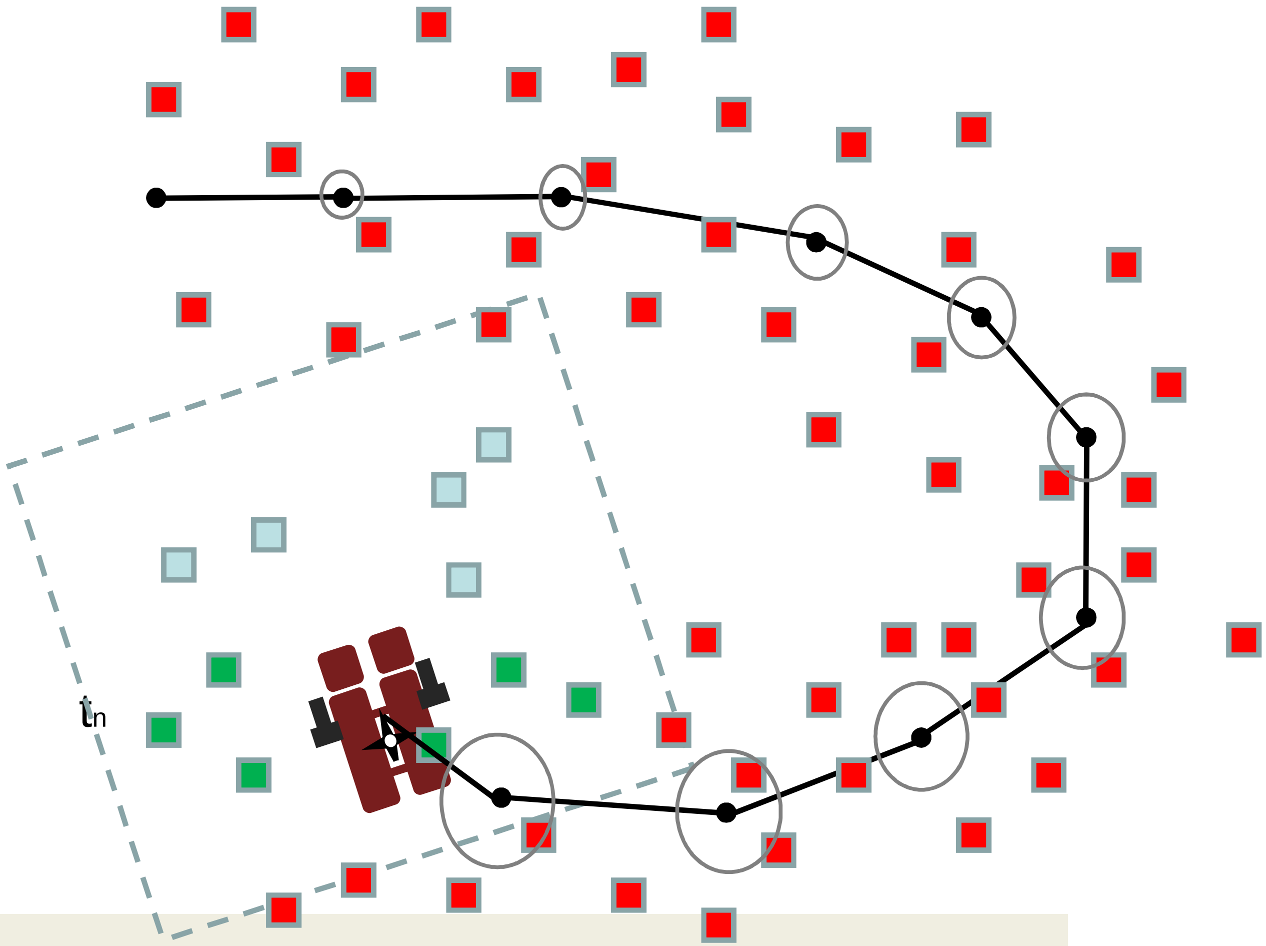
Pose-Based SLAM II



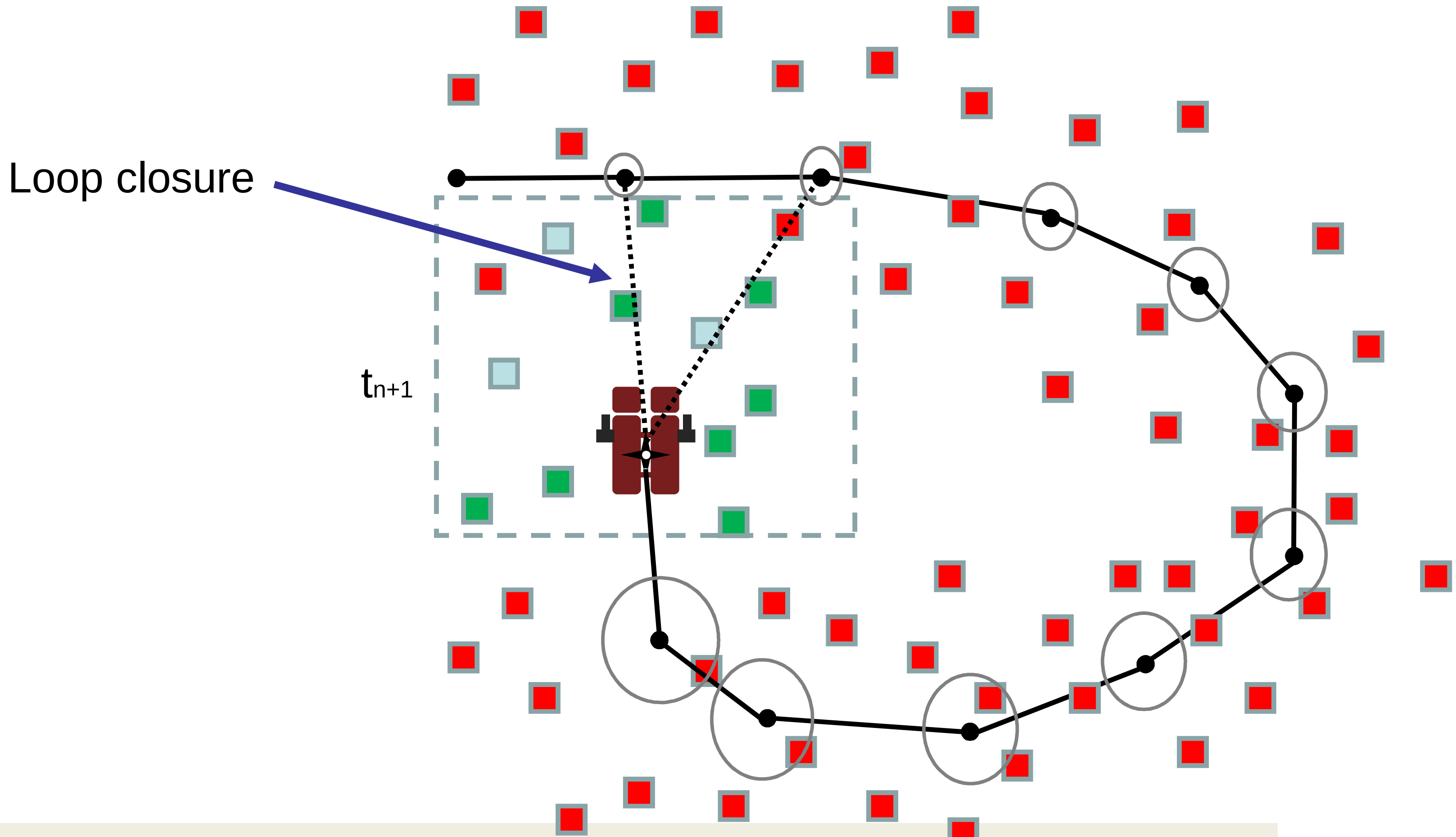
Pose-Based SLAM III



Pose-Based SLAM IV



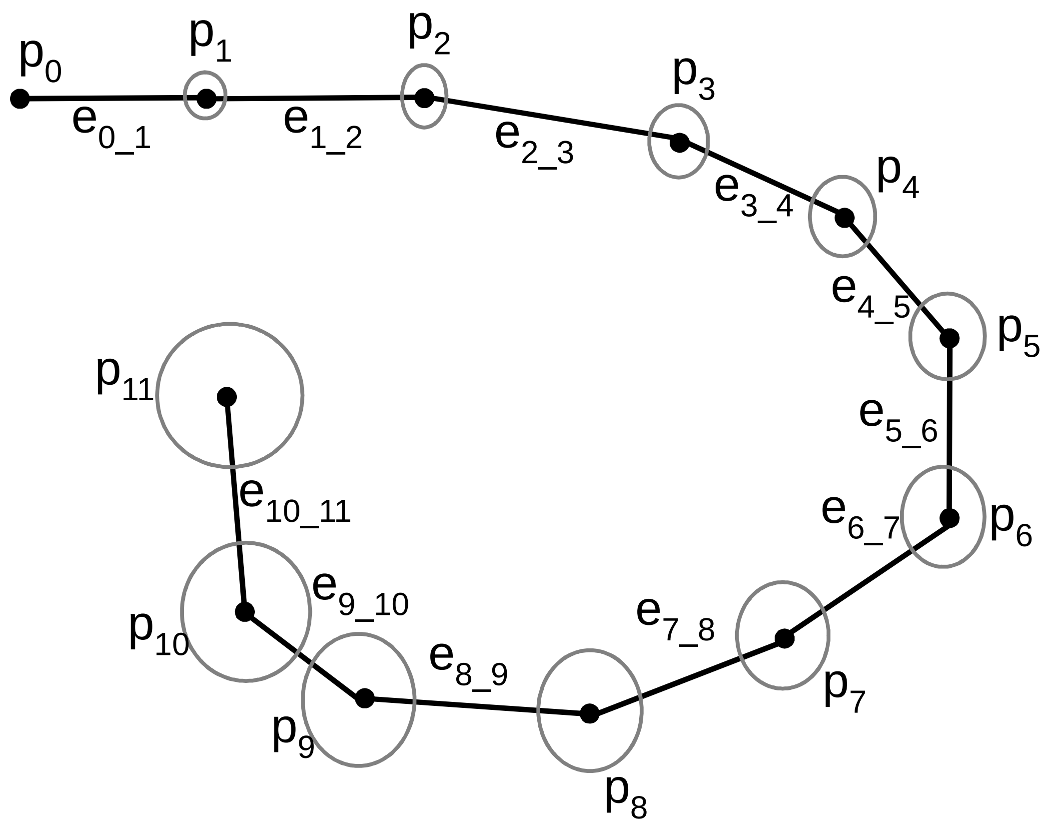
Pose-Based SLAM V



Pose-Based SLAM VI

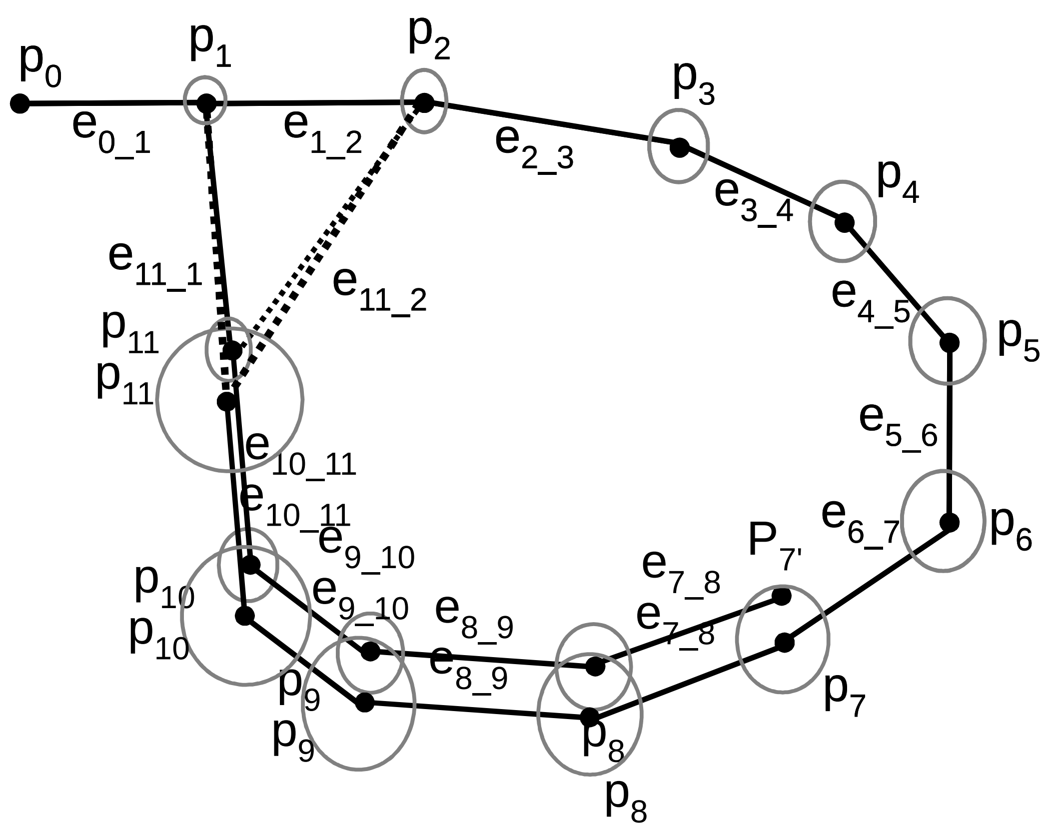
- Without loop closing:
- $p_i = p_{i-1} + e_{i-1\_i}$
- $u_i = u_{i-1} + w_{i-1\_i}$

→ No upper bound for error



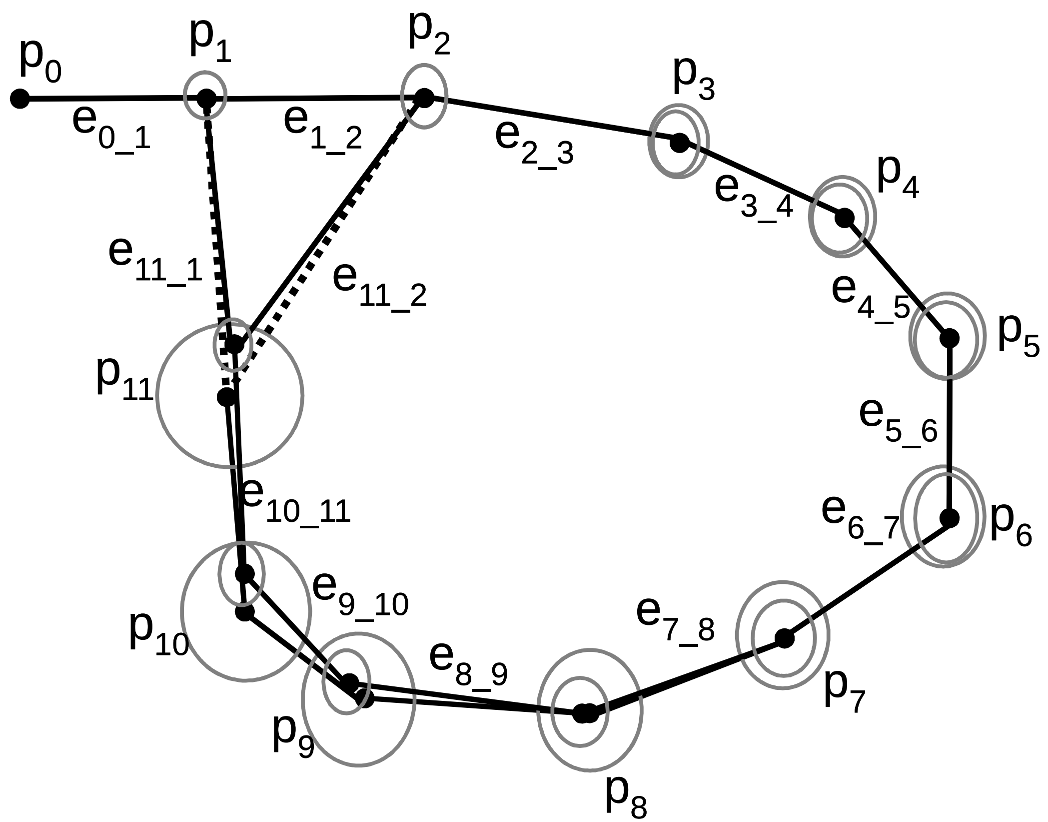
Pose-Based SLAM VII

- loop closing adds additional information e_{11_1} and e_{11_2}
- How to handle this?
- Option 1:
- Use shortest path in graph
  - → Reduces max error
  - → Only uses part of the new information
  - → Creates gap



Pose-Based SLAM VIII

- Option 2:
- Use graph-based optimization algorithm
- G2O (general graph optimization)
  - Uses all information
  - “relaxes” graph structure
  - Results in optimal graph



AUV Dagon