海中環境に適応する高度なAUVナビゲーション

Advanced AUV Navigation adapting to Underwater Environments

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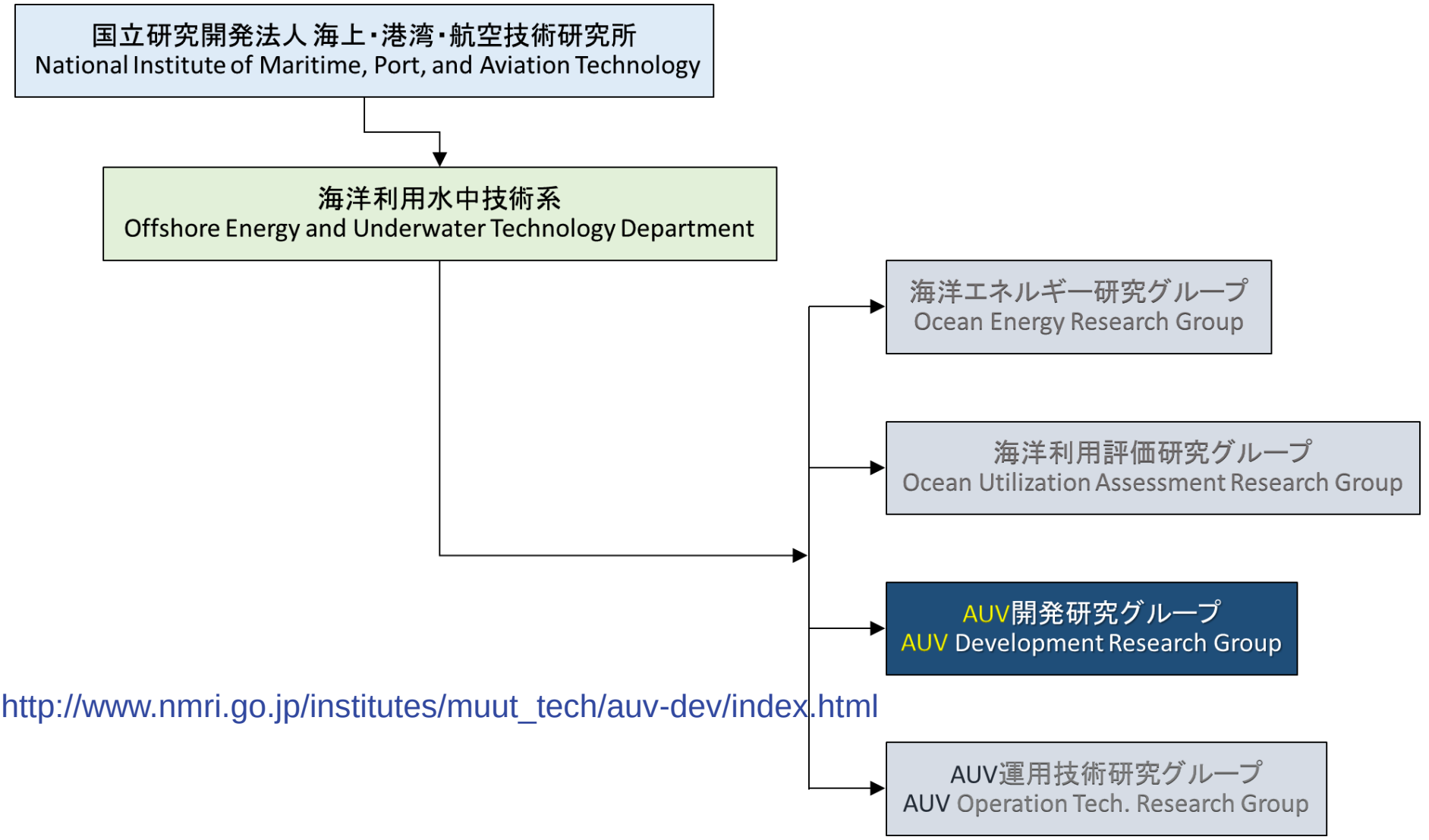
What is AUV ?



http://www.nmri.go.jp/institutes/muut_tech/auv-dev/index.html

AUV : Autonomous Underwater Vehicle

AUV-Based Ocean Survey

Advantages

- free from the risk in human life
- low operation cost
- unconstrained motion

Challenges

- unable to operate remotely in a real-time manner
- requires highly sophisticated autonomy

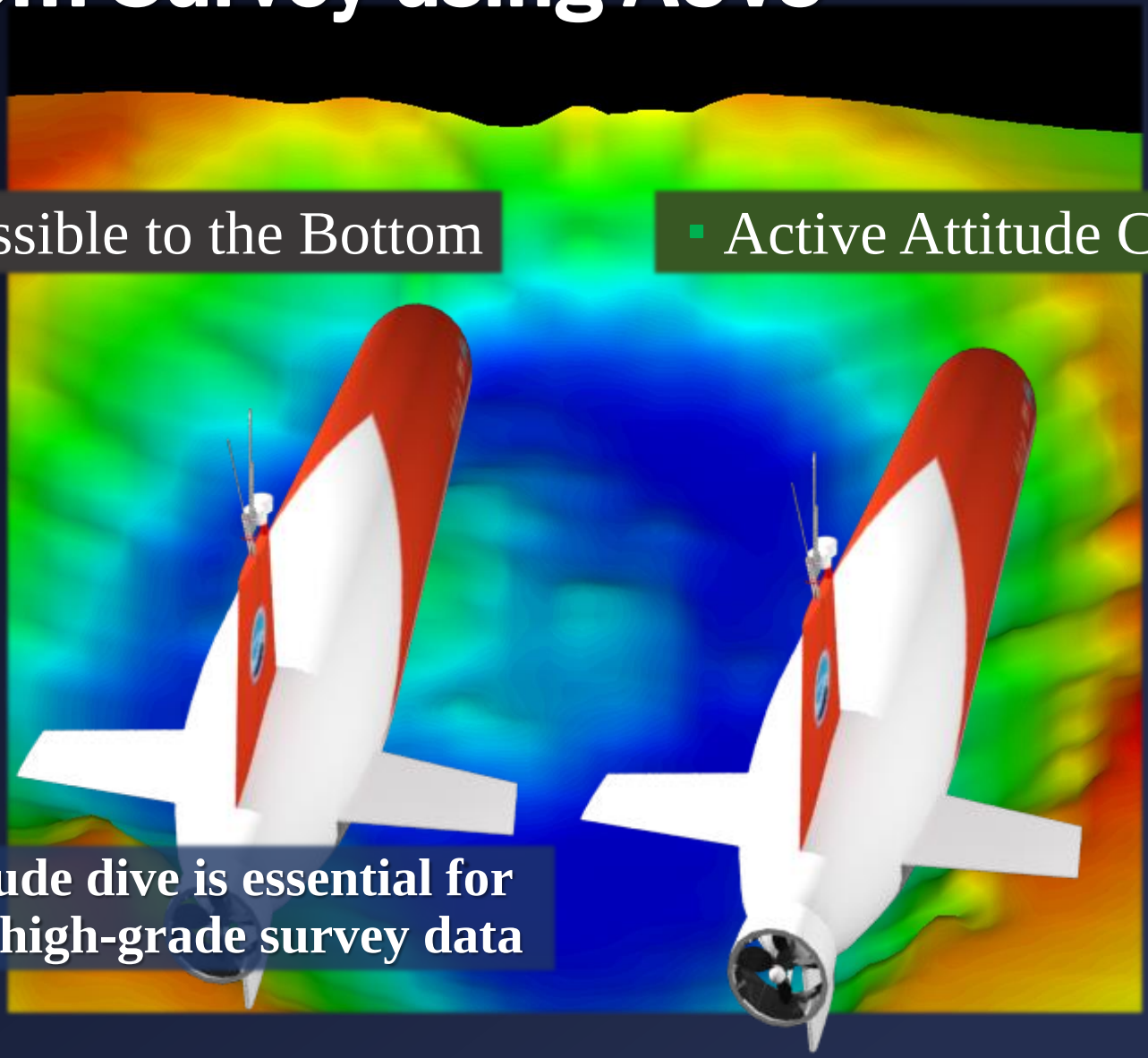
- An AUV operates independently from the ship and has no connecting cables whereas ROVs are connected to an operator on the ship

Navigation, Guidance, and Control

- Navigation refers to the process to find the present and future position of a vehicle
- Guidance refers to the process to define a path to move a vehicle from one point to another
- Control refers to the process to maintain a vehicle to follow the prescribed path and attitude

Bottom Survey using AUVs

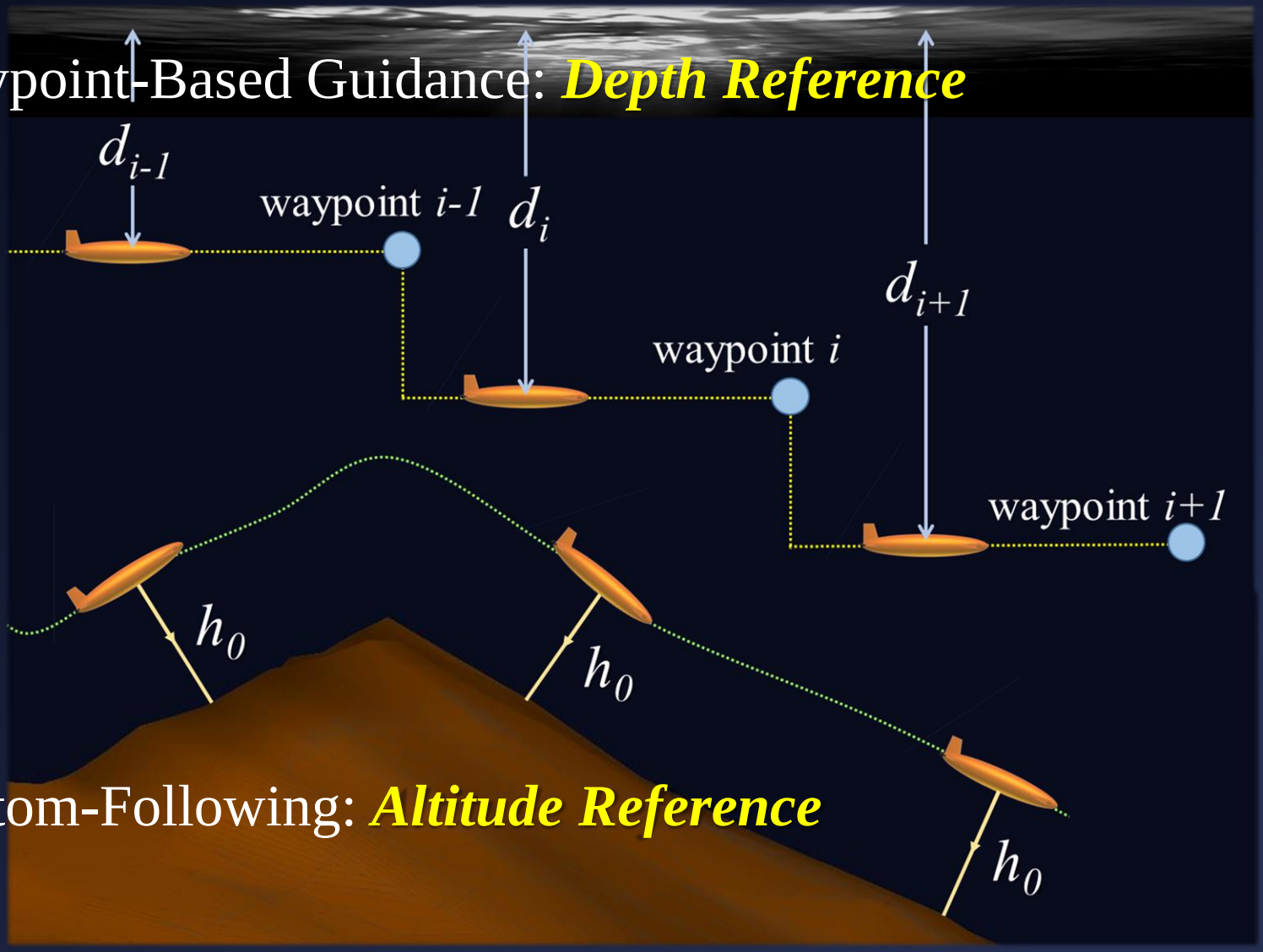
- Accessible to the Bottom
- Active Attitude Control



Low-altitude dive is essential for collecting high-grade survey data

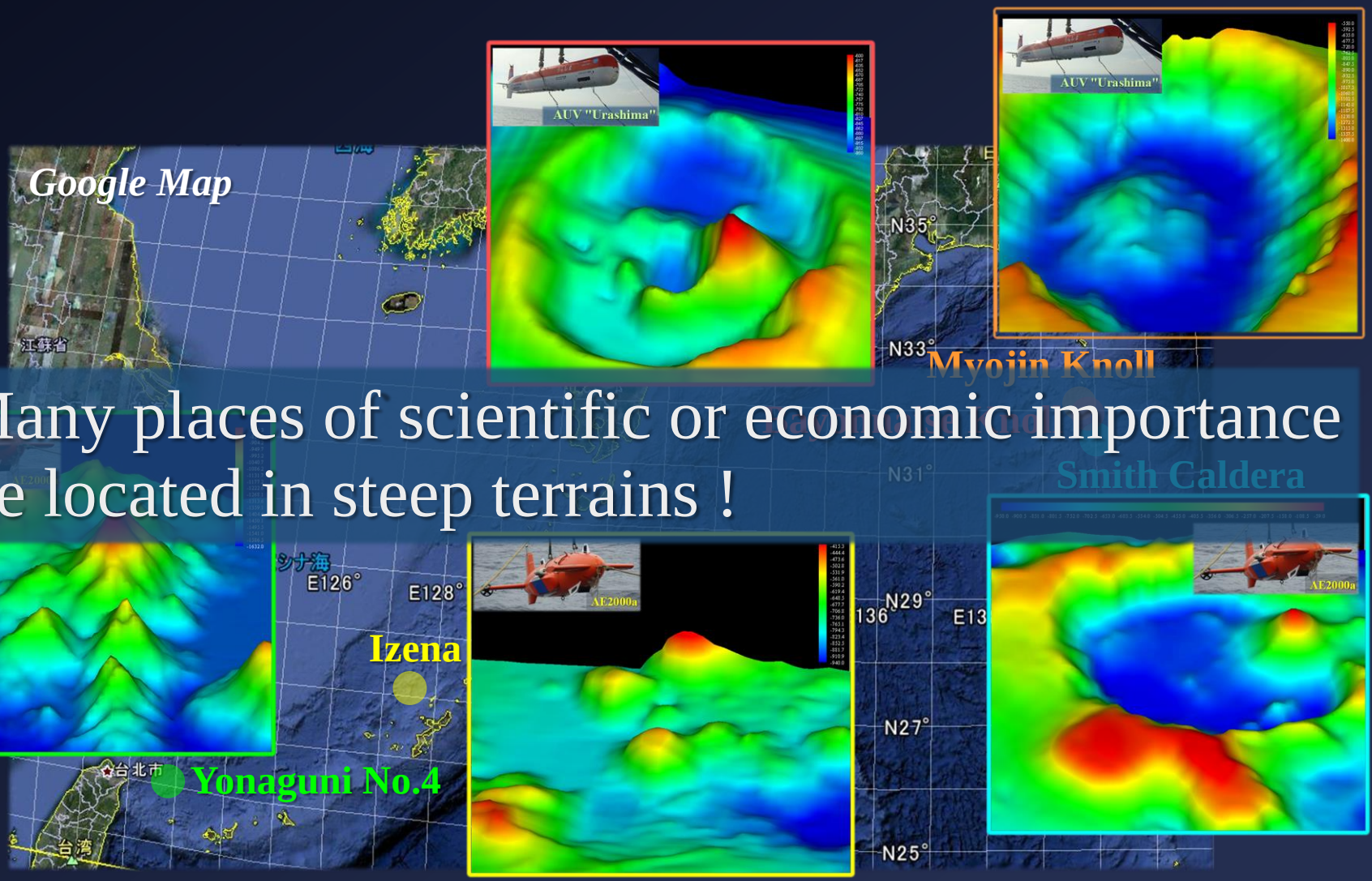
Basic Strategies for AUV-Based Bottom Survey

- Waypoint-Based Guidance: ***Depth Reference***



- Bottom-Following: ***Altitude Reference***

Steep, Uneven Sea Bottoms

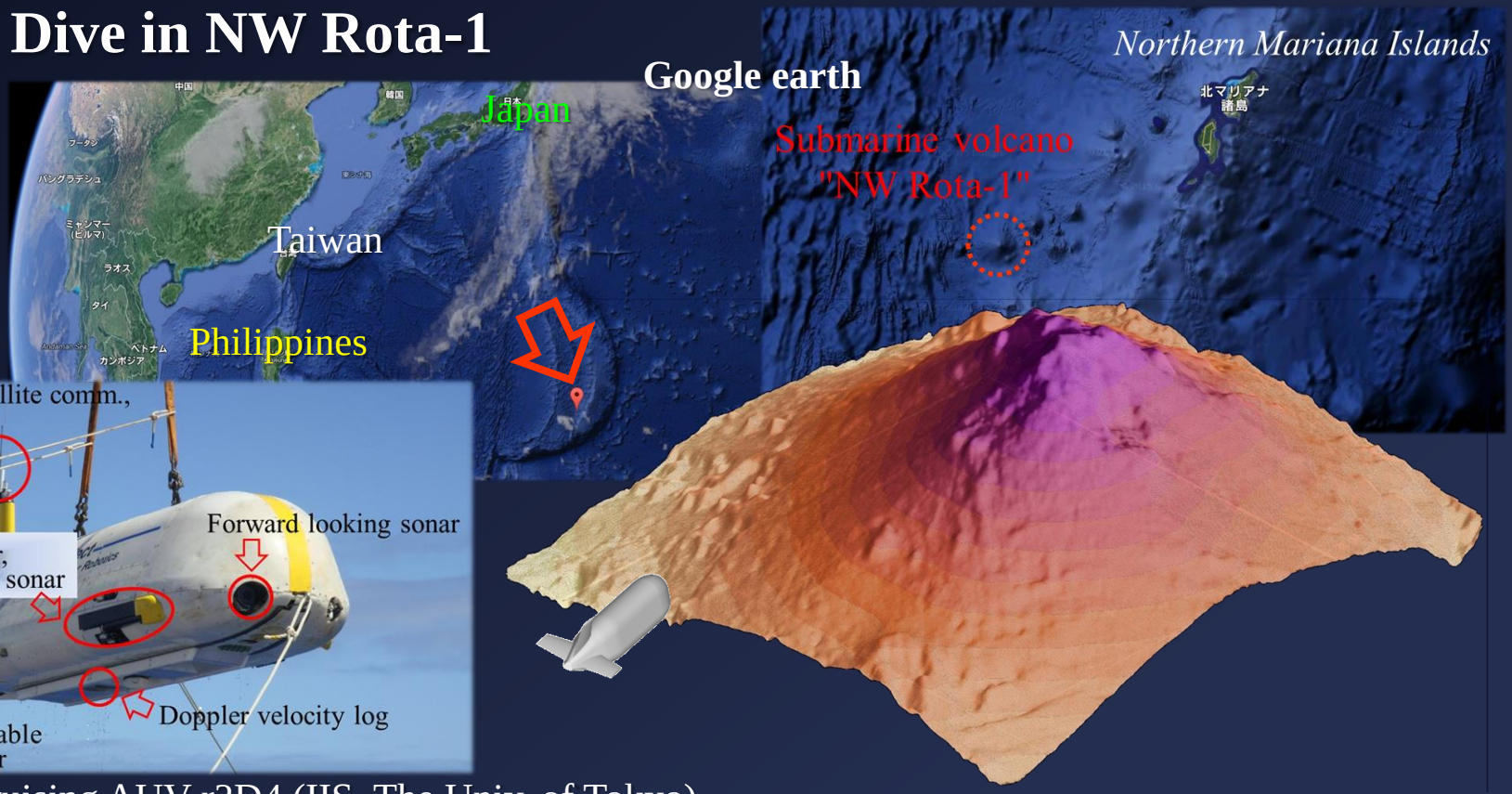


- Many places of scientific or economic importance are located in steep terrains !

Sources of Bottom Collision of a Cruising AUV

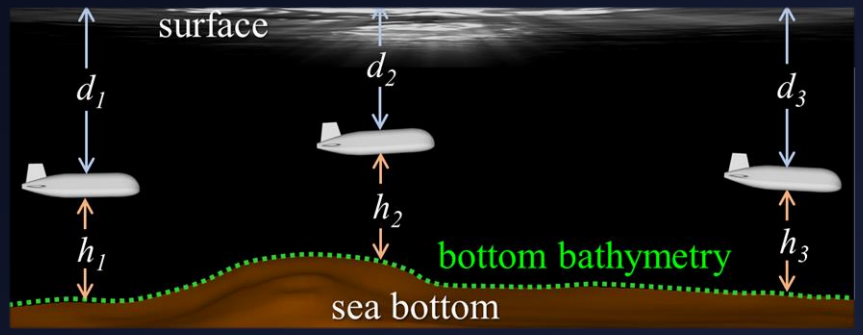
- steep terrain
- limits in vehicle dynamics
- **unreliable information on the bottom**

- **r2D4 Dive in NW Rota-1**

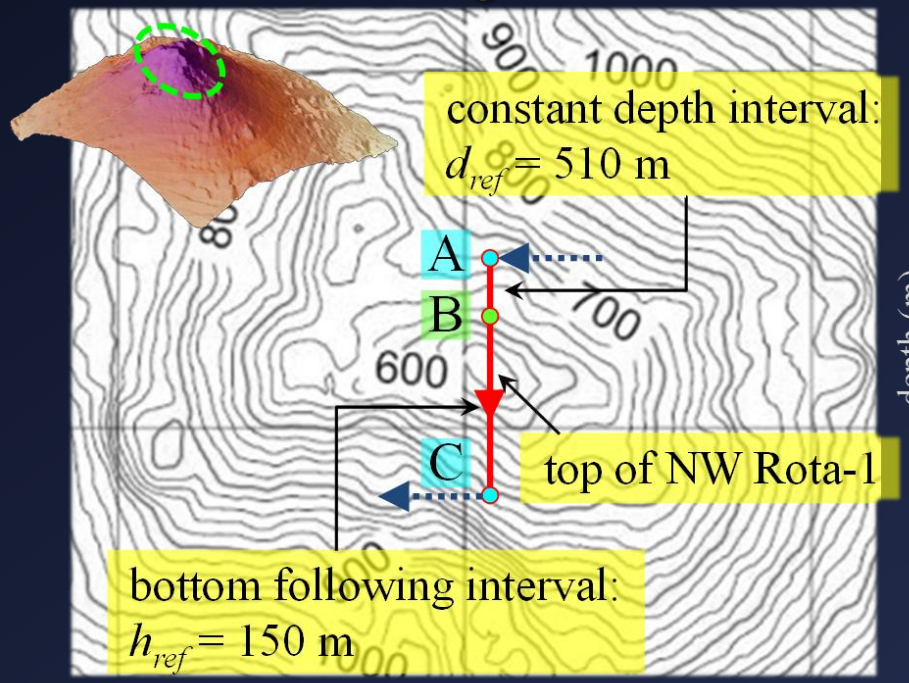


Cruising AUV r2D4 (IIS, The Univ. of Tokyo)

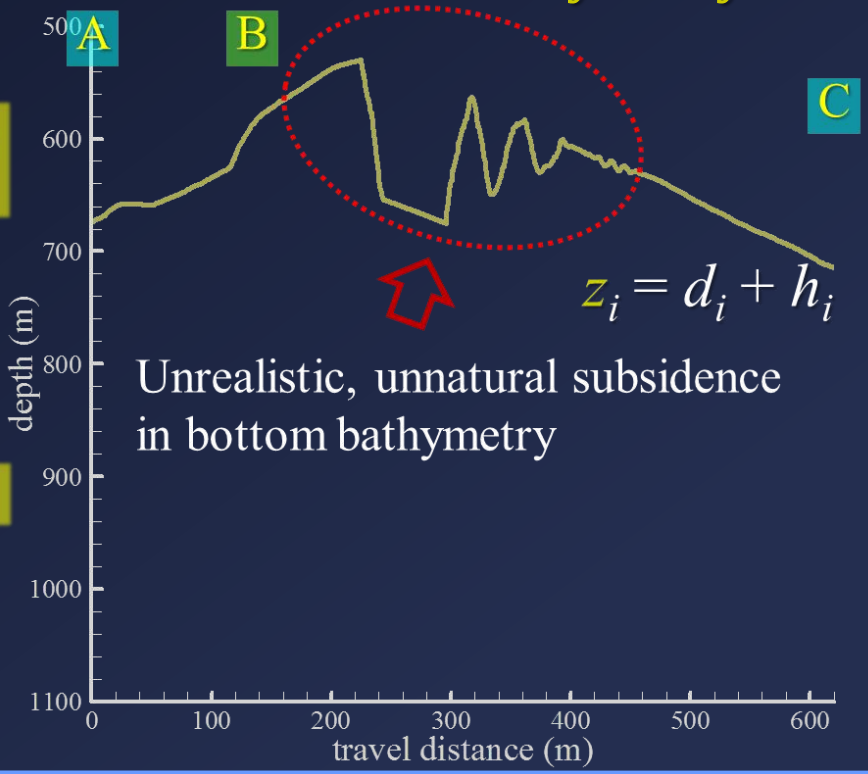
Unrealistic Bottom Bathymetry



Navigation

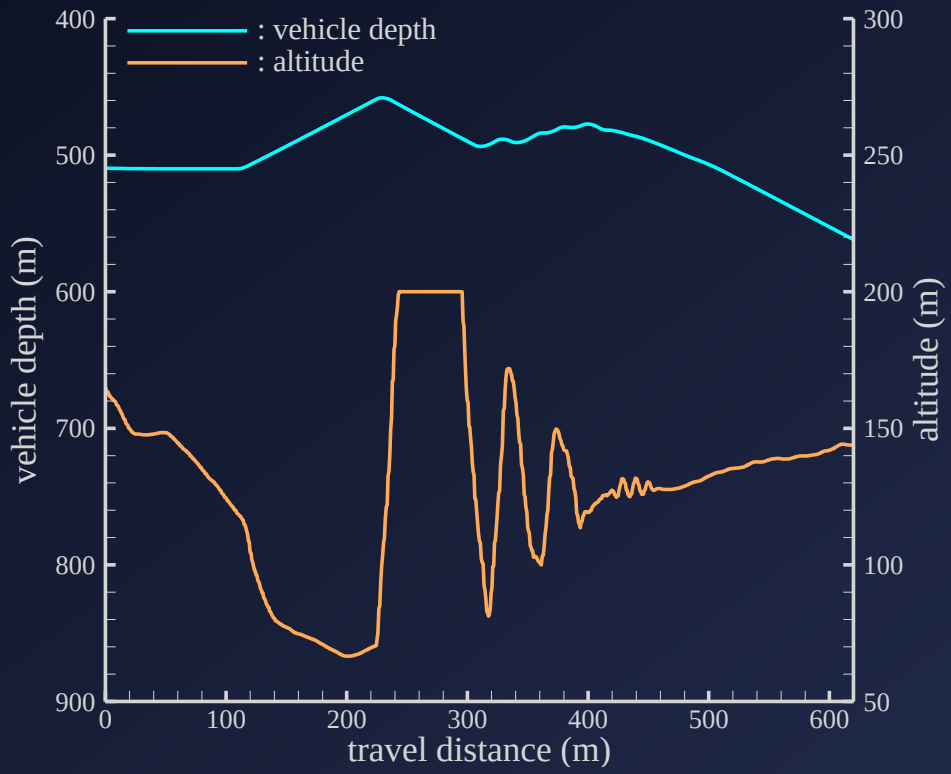


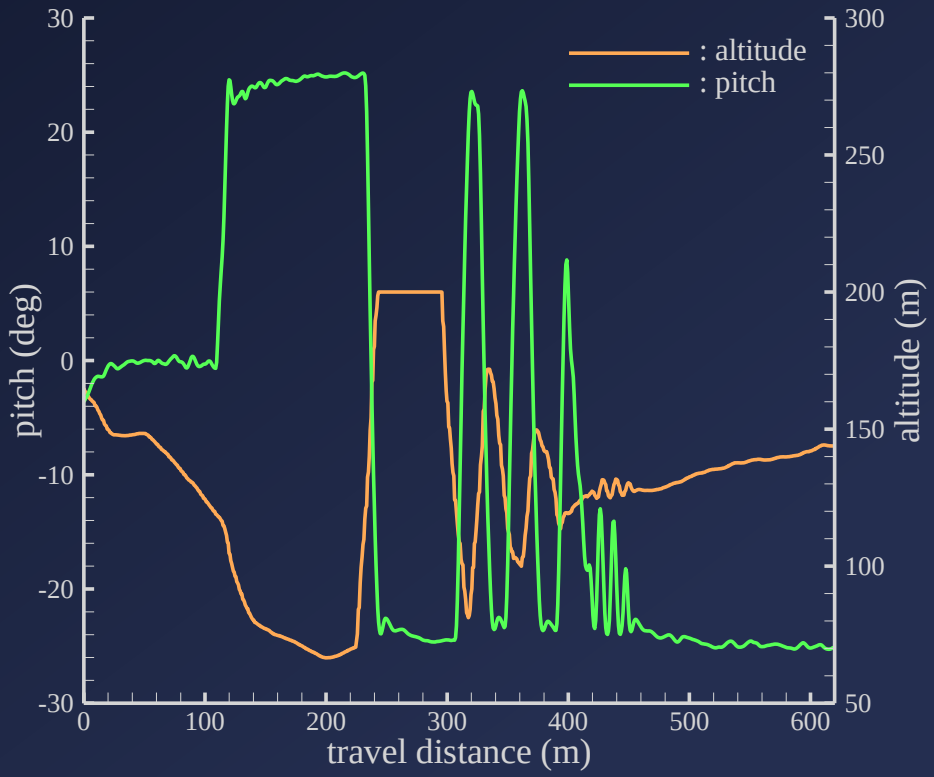
Bottom Bathymetry



Depth, Altitude, and Pitch

- ***Unrealistic altitude fluctuation***
- ***Depth and pitch also fluctuate, but are realistic***



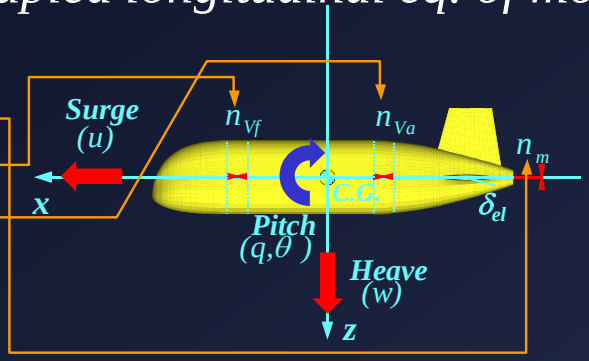


Dive Simulation

- model-based investigation of the motion instability

  - Vehicle dynamics: *coupled longitudinal eq. of motion*

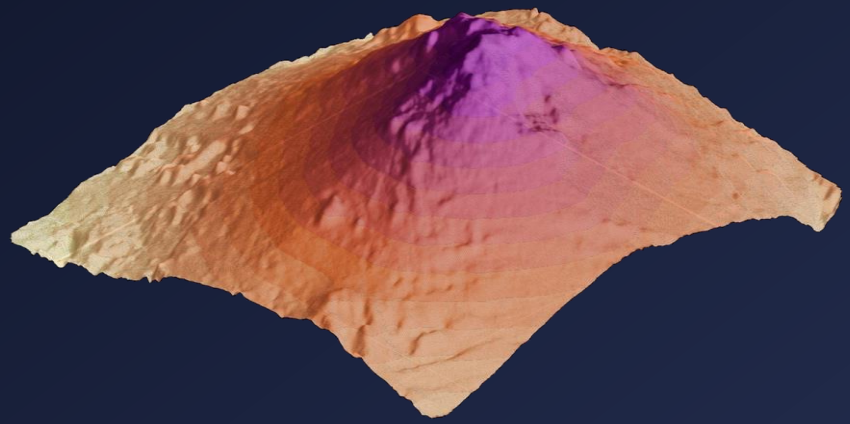
$$\begin{bmatrix} \dot{u} \\ \dot{w} \\ \dot{q} \\ \dot{\theta} \end{bmatrix} = [A_{lon}] \begin{bmatrix} u \\ w \\ q \\ \theta \end{bmatrix} + [B_{lon}] \begin{bmatrix} n_m \\ n_{Vf} \\ n_{Va} \\ \delta_{el} \\ \delta_{er} \end{bmatrix}$$

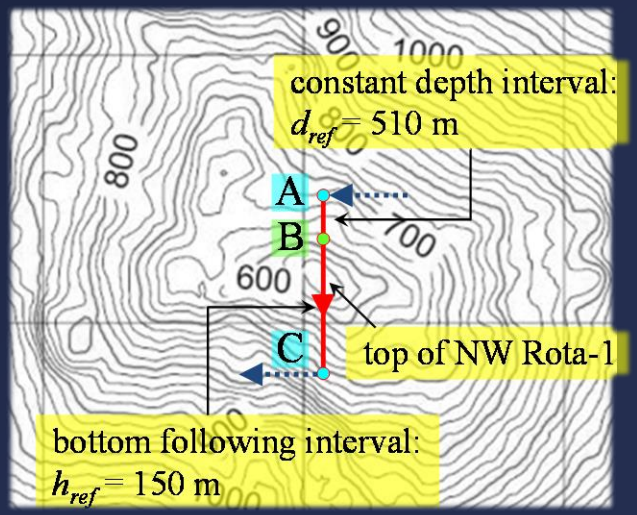


  - Navigation:

    const. depth + bottom following (actual dive)

  - Bottom geometry: *NW Rota-1*

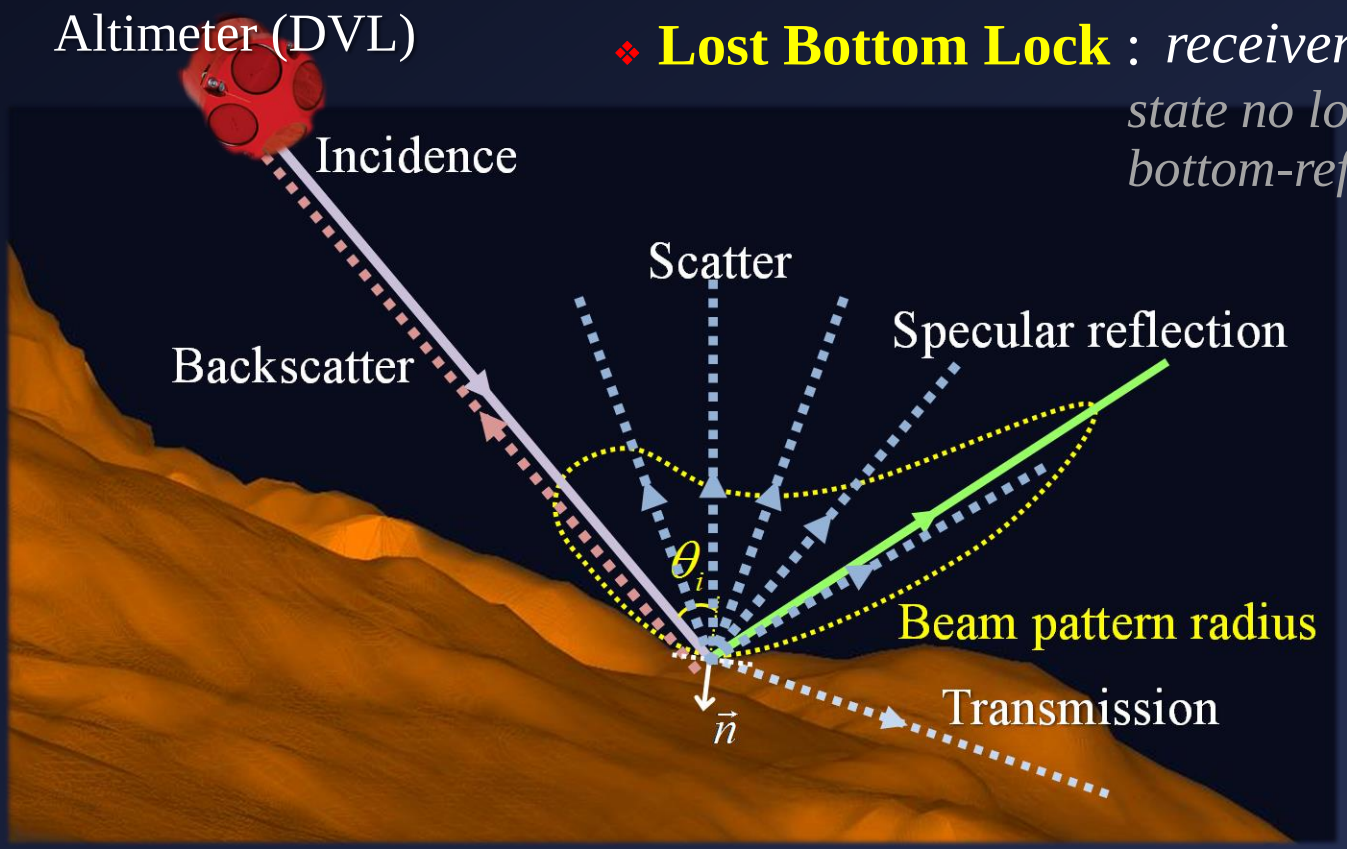




Underwater Acoustics

- Sonar equation: Receiver $SNR = SL - 2TL - TS - NL$
- Transmission Loss *(TL)*: $20log_{10}R + \alpha R$
- Target Strength *(TS)* : ➡ ***Angular dependence of bottom scattering***

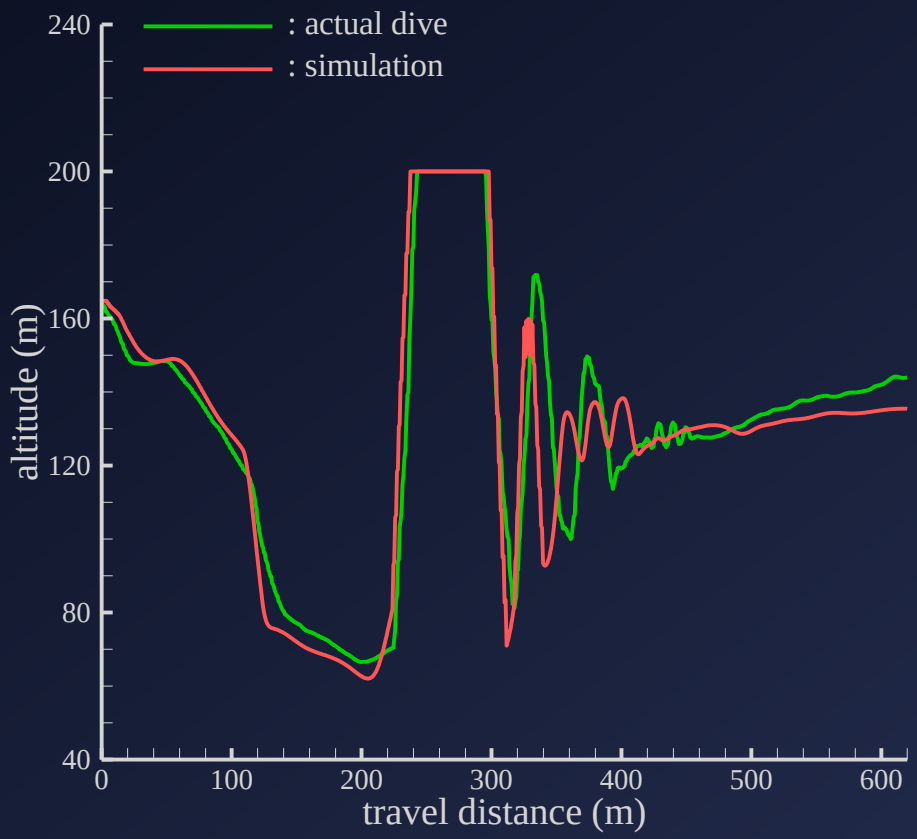
SL: Source Level
NL: Noise Level



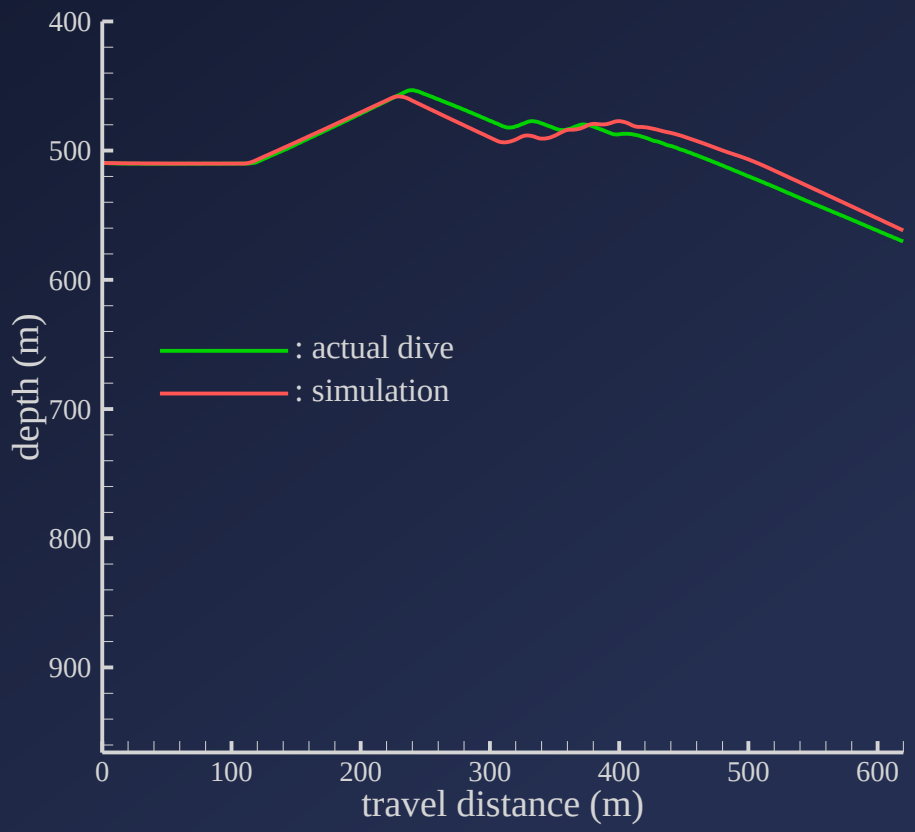
❖ **Lost Bottom Lock** : *receiver SNR* < threshold *SNR*
state no longer able to provide any bottom-reference measurements

Results of Dive Simulation

- Altitude

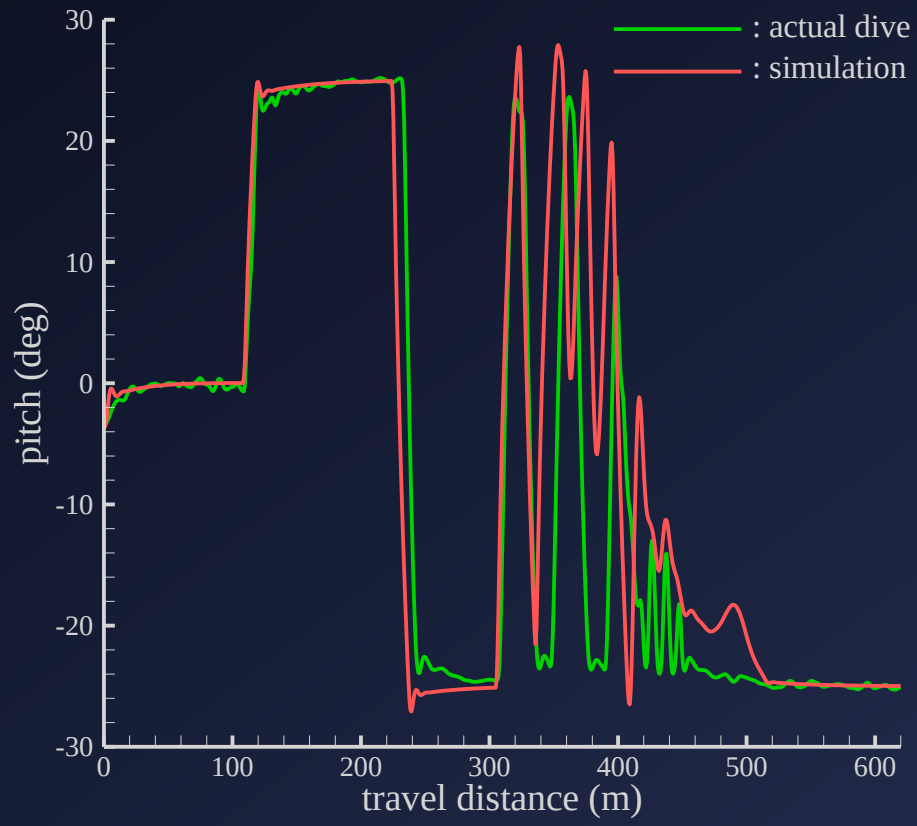


- Vehicle depth

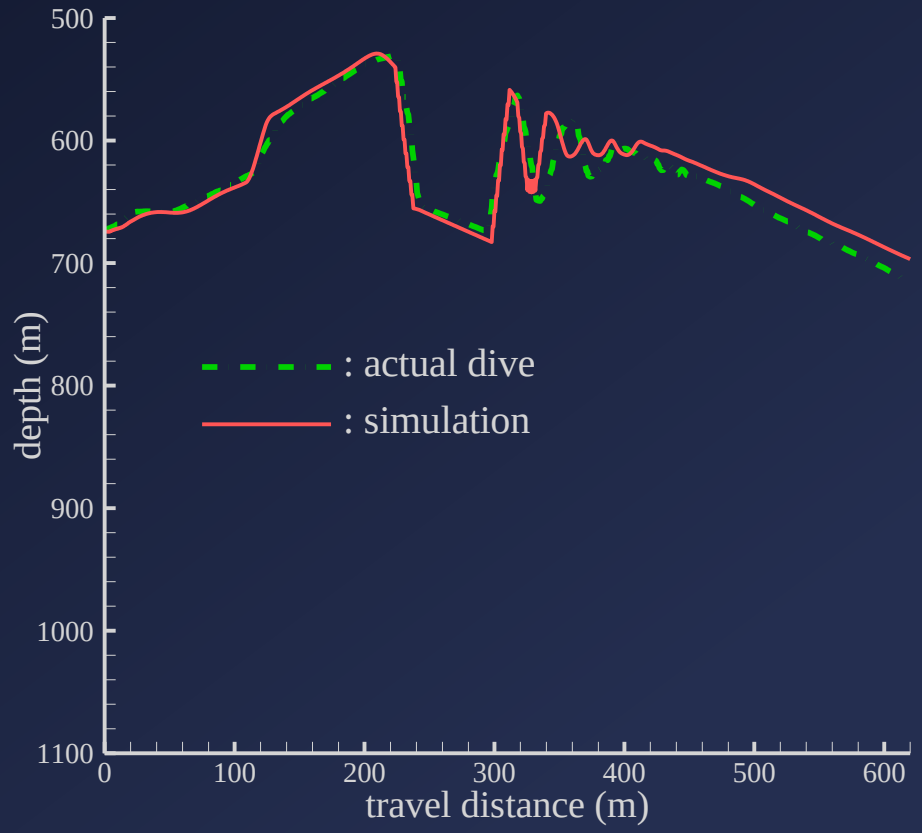


Results of Dive Simulation

- Pitch

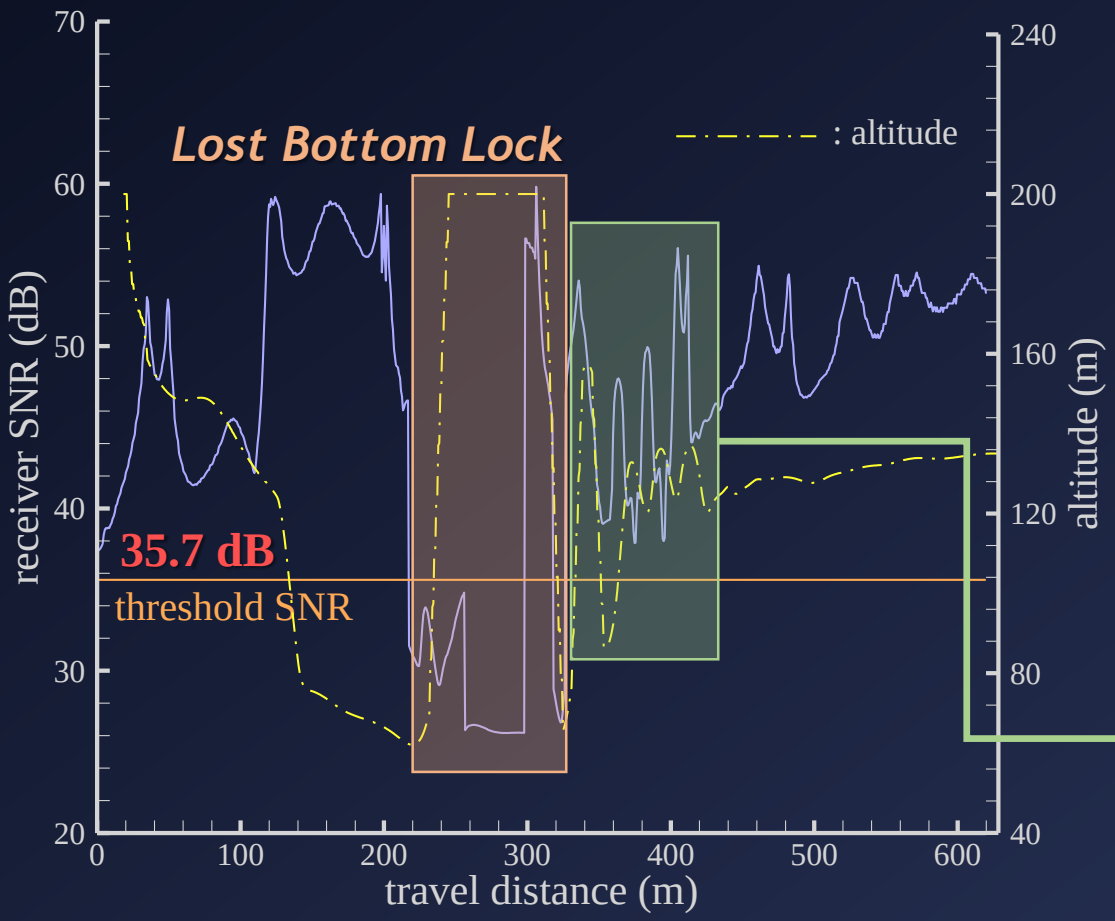


- Bottom bathymetry



Diagnosis

- **Simulated receiver SNR**



- **Lost Bottom Lock**

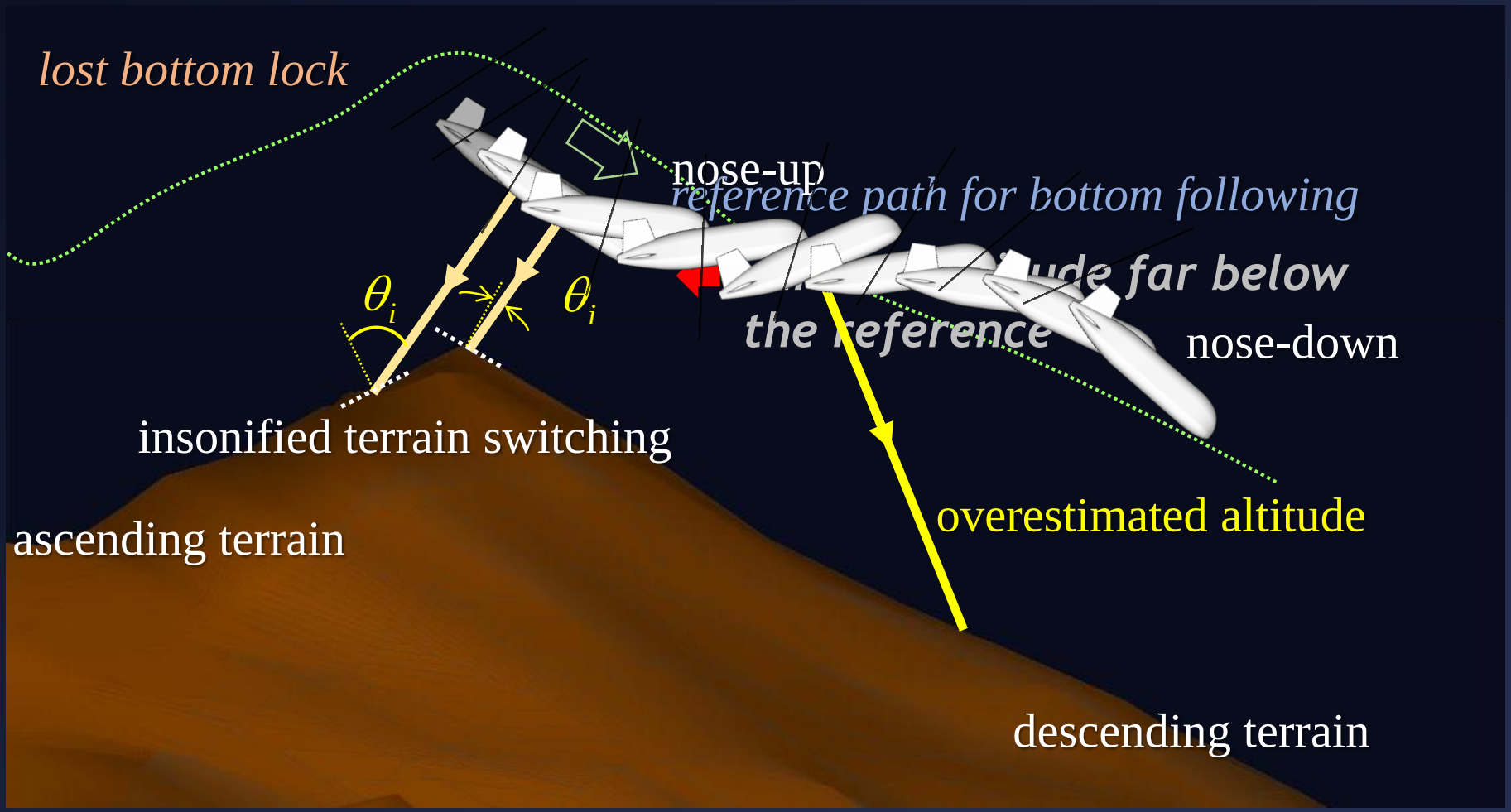
➡ **Angular dependence of bottom scattering**

✓ *10-points moving average filter*

✓ *Default indicated altitude in case of lost bottom lock : 200 m*

Motion instability NOT caused by Lost Bottom Lock

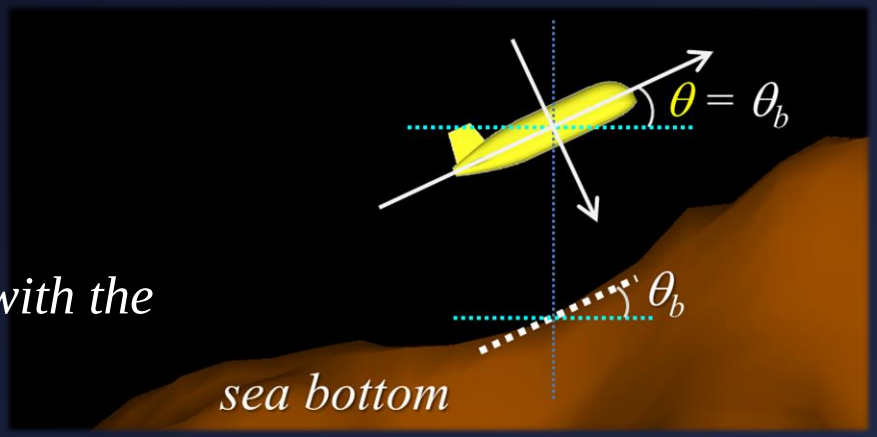
Nodding Motion due to Altitude Overestimation

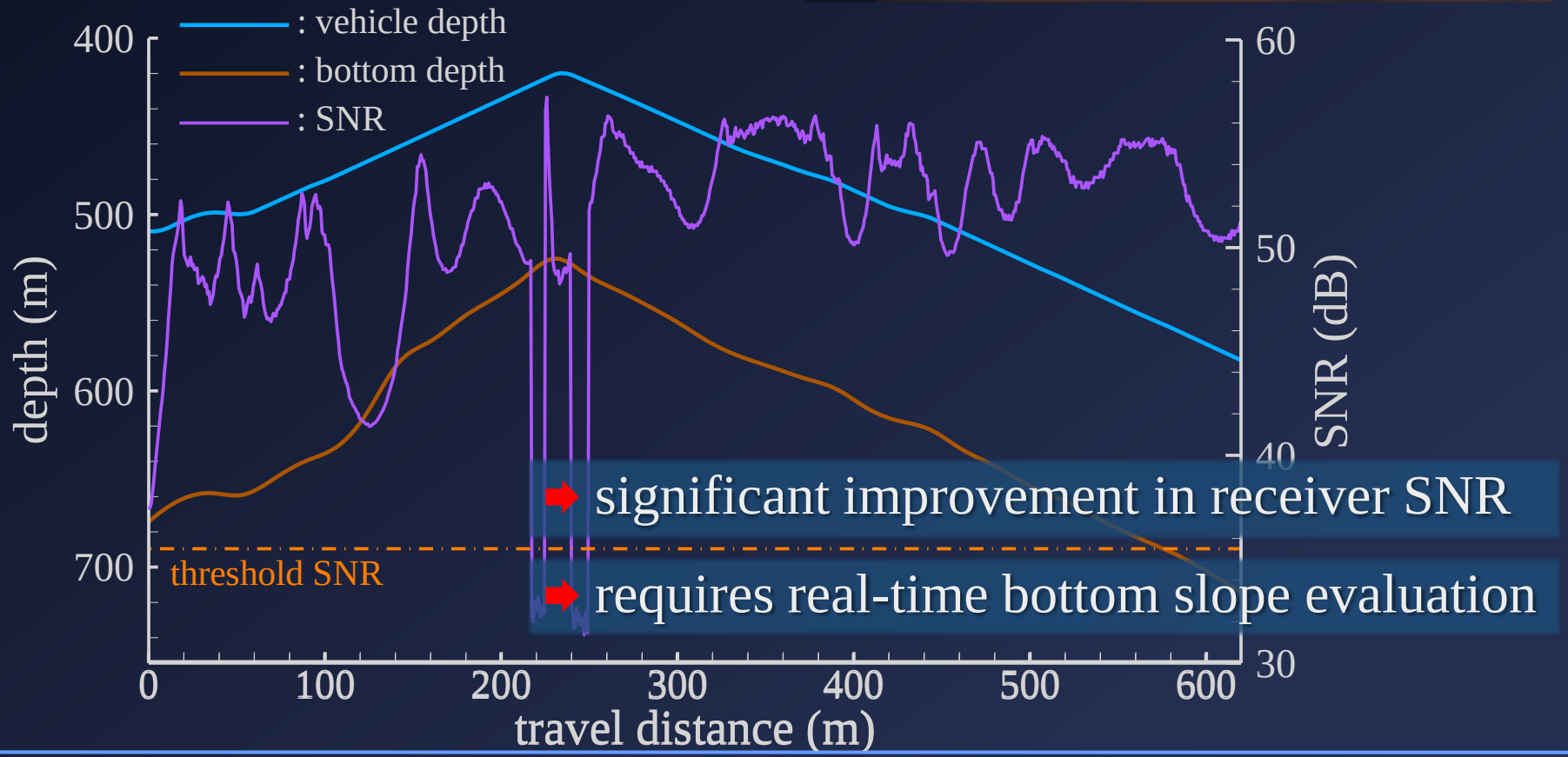


Solutions

- **Slope-Following Dive**

  control the pitch of a vehicle to coincide with the slope of sea bottom

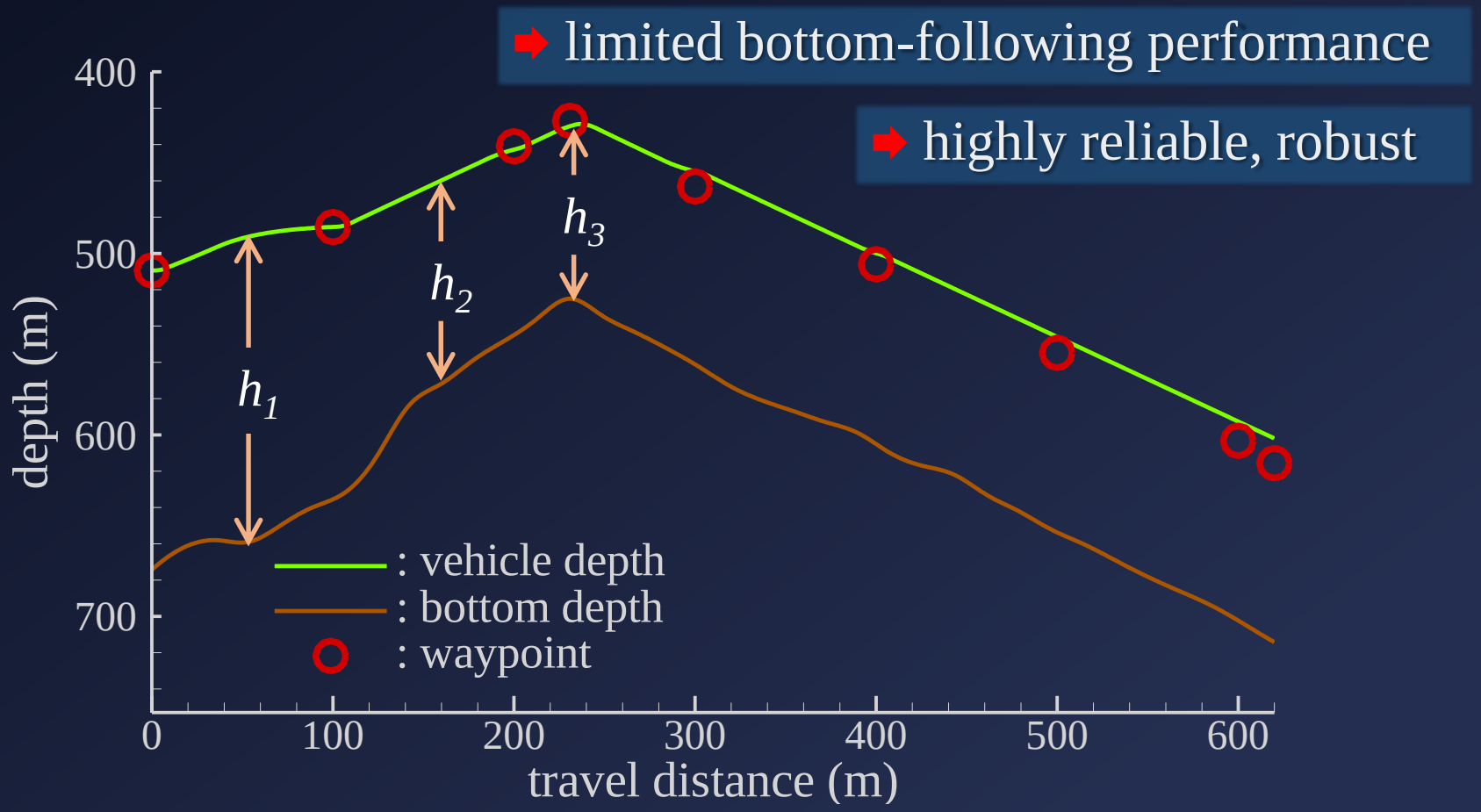




Solutions

- **Pseudo Bottom-Following Dive**

- depth referencing waypoint-based guidance emulating bottom following



Conclusions and Future Works

- Navigation of a cruising AUV over a Steep Terrain

  - *vehicle safety*
  - *low altitude access*
  - *attitude stability*

  ⇨ ***cannot be satisfied by conventional depth or altitude based navigation***

- Terrain-Adaptive AUV Navigation

  - *Slope-Following Dive*
  - *Pseudo Bottom-Following Dive*

Acknowledgements

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