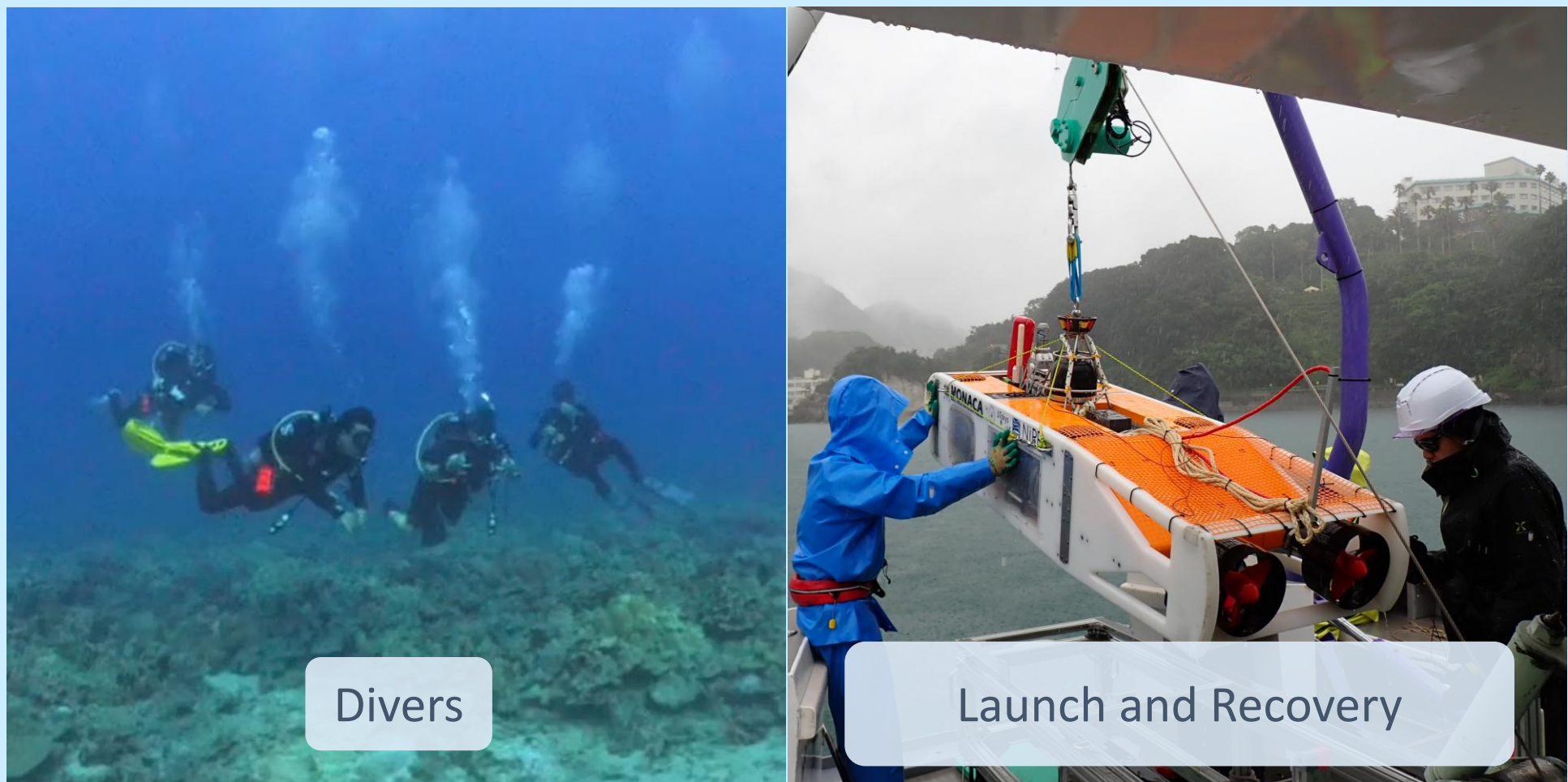


INTRODUCTION

Scalable self-localization for compact autonomous underwater vehicle and autonomous surface vehicle (AUV-ASV) systems enables safe, cost-effective, and versatile subsea operations compared to conventional approaches.



Safety risks, operation time & cost constraints

Towards

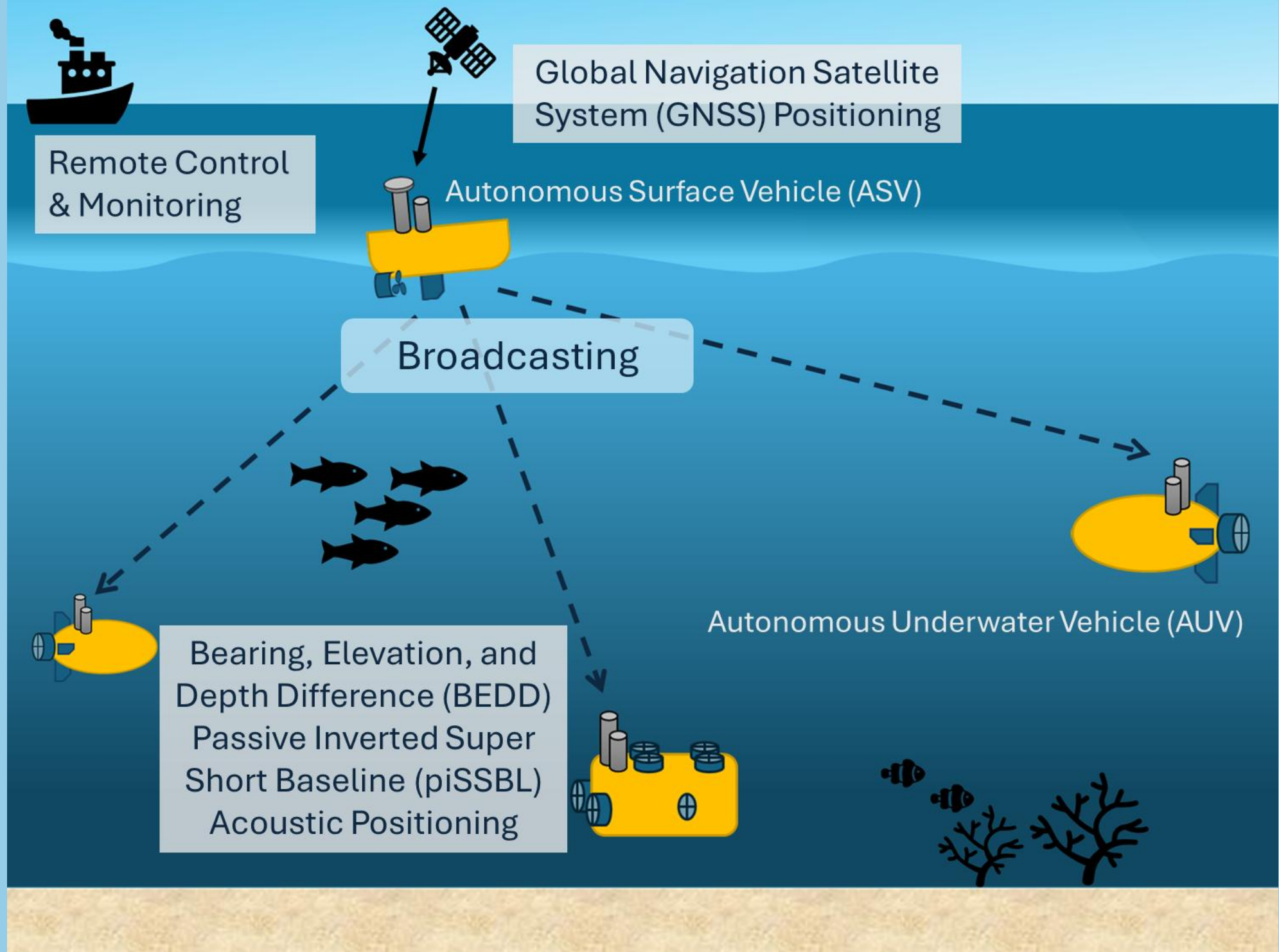
- Autonomous
 - Portable
 - Scalable
- subsea operations



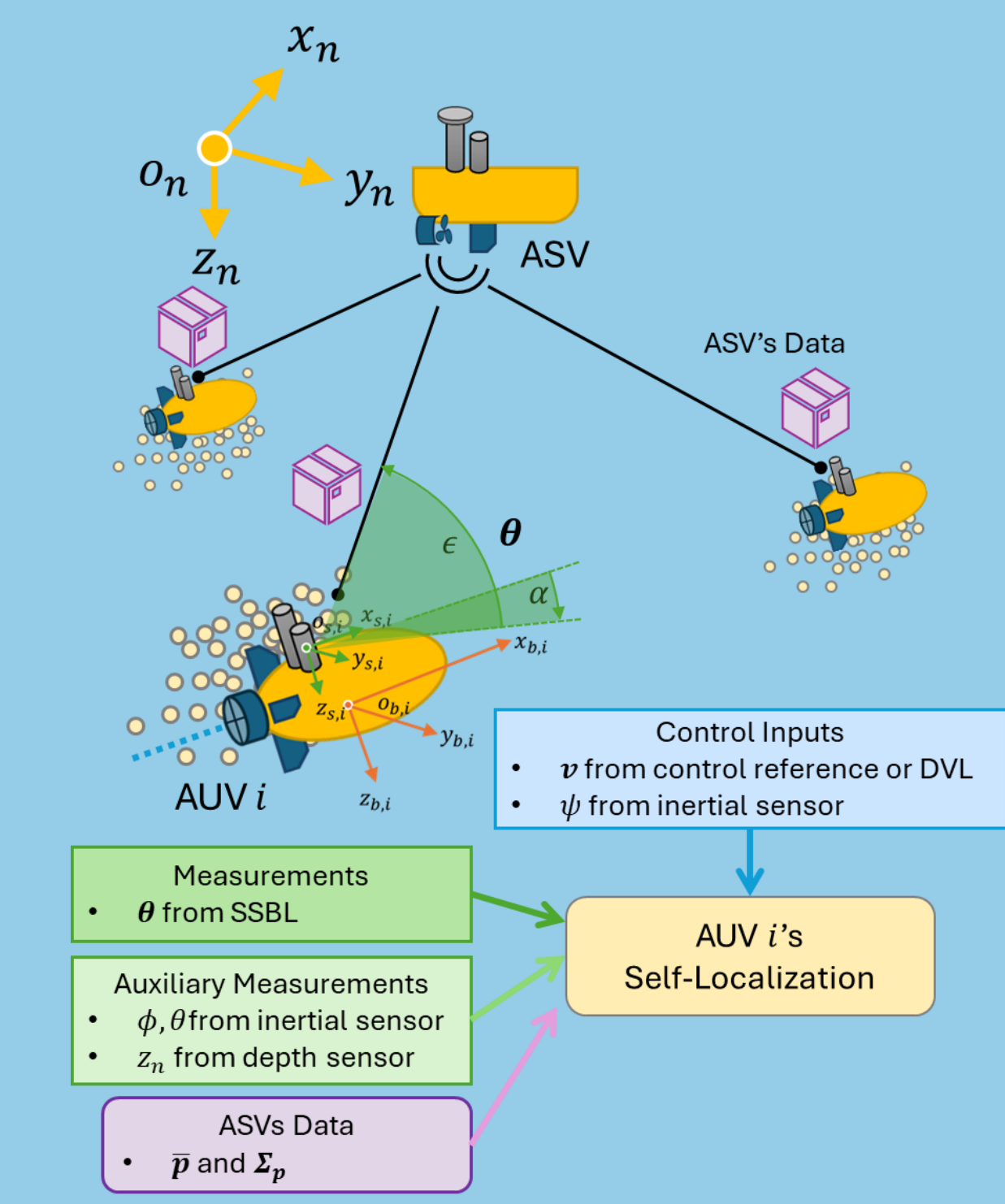
Compact, portable, safe, and easy to operate

PROPOSED METHOD

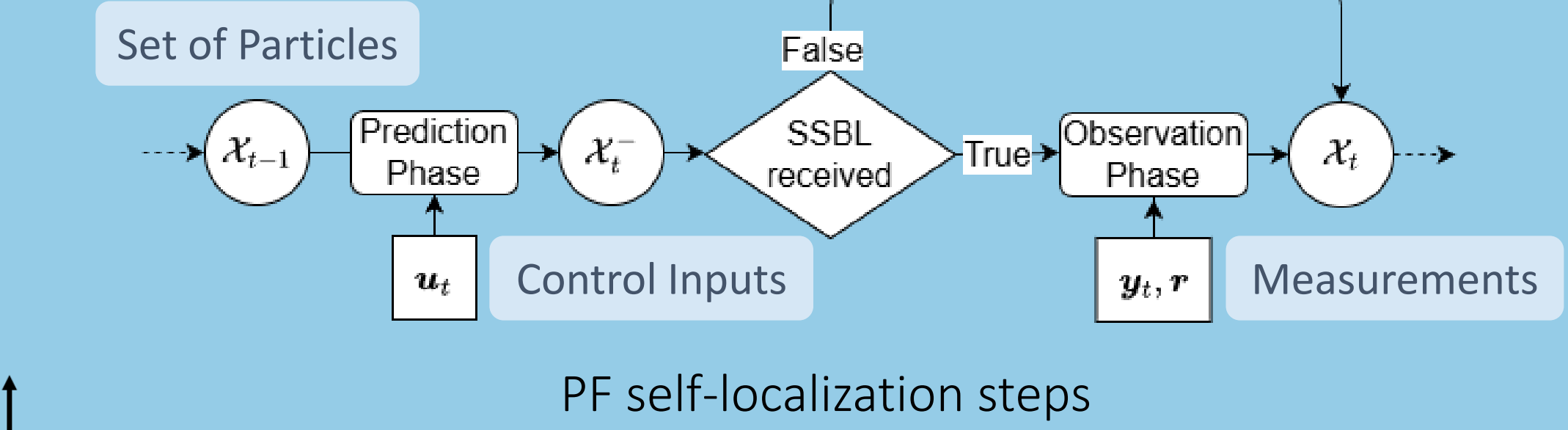
Fuses AUV navigation sensors, ASV-repeated Global Navigation Satellite System (GNSS) positions, and bearing, elevation, and depth difference (BEDD) passive inverted super short baseline (piSSBL) acoustic positioning via a particle filter (PF) with adaptive sensor reset for scalable multi-robot localization.



GNSS-acoustic positioning for AUV-ASV operations



Scalable underwater acoustic self-localization



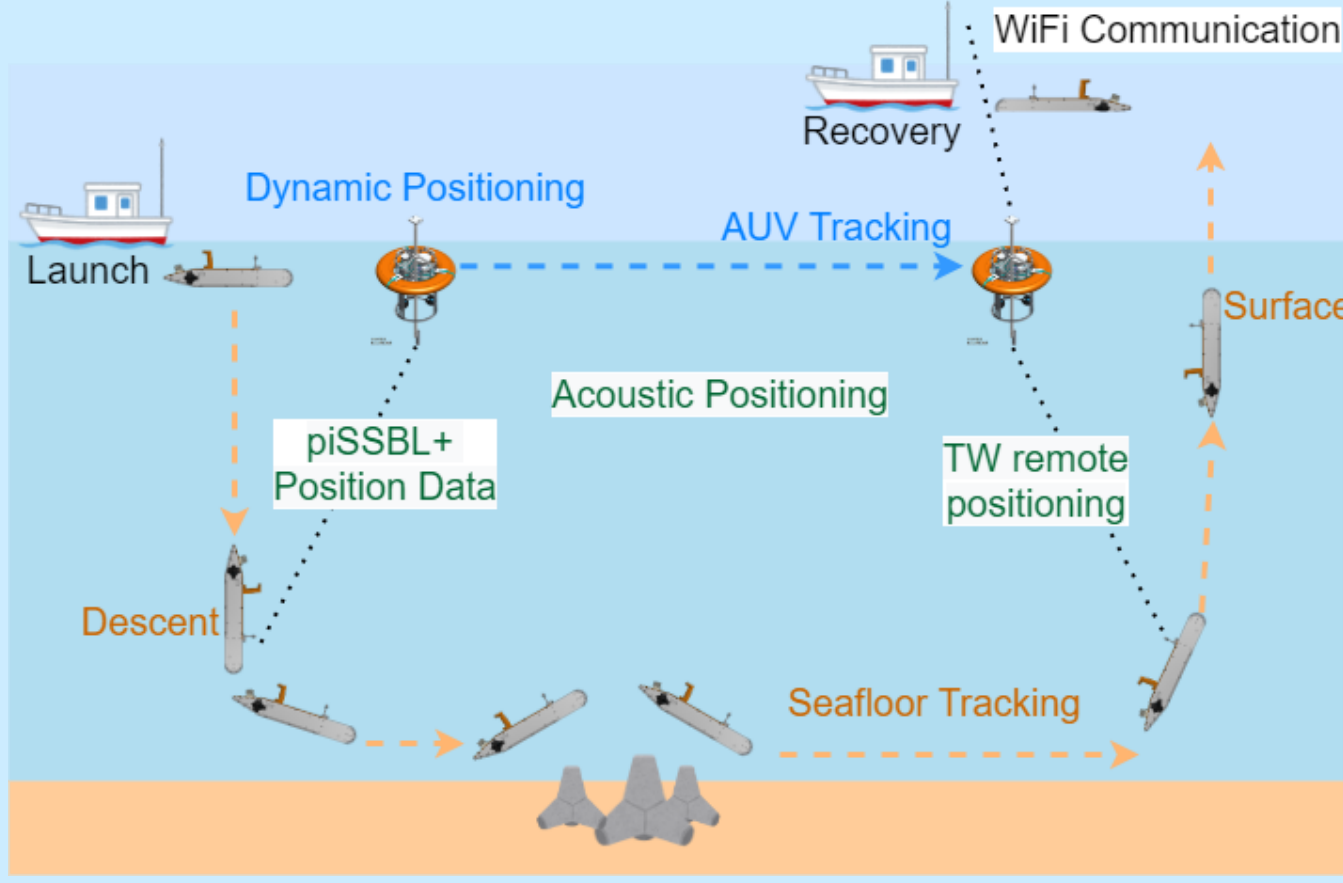
- An ASV broadcasts its GNSS-based position to the AUVs via acoustic communication
- North (x) and east (y) position PF estimates using the BEDD measurements
- Initialized using GNSS, if available

BEDD acoustic positioning [1] adaptive sensor reset [2]
within the observation phase of the PF

EXPERIMENTS

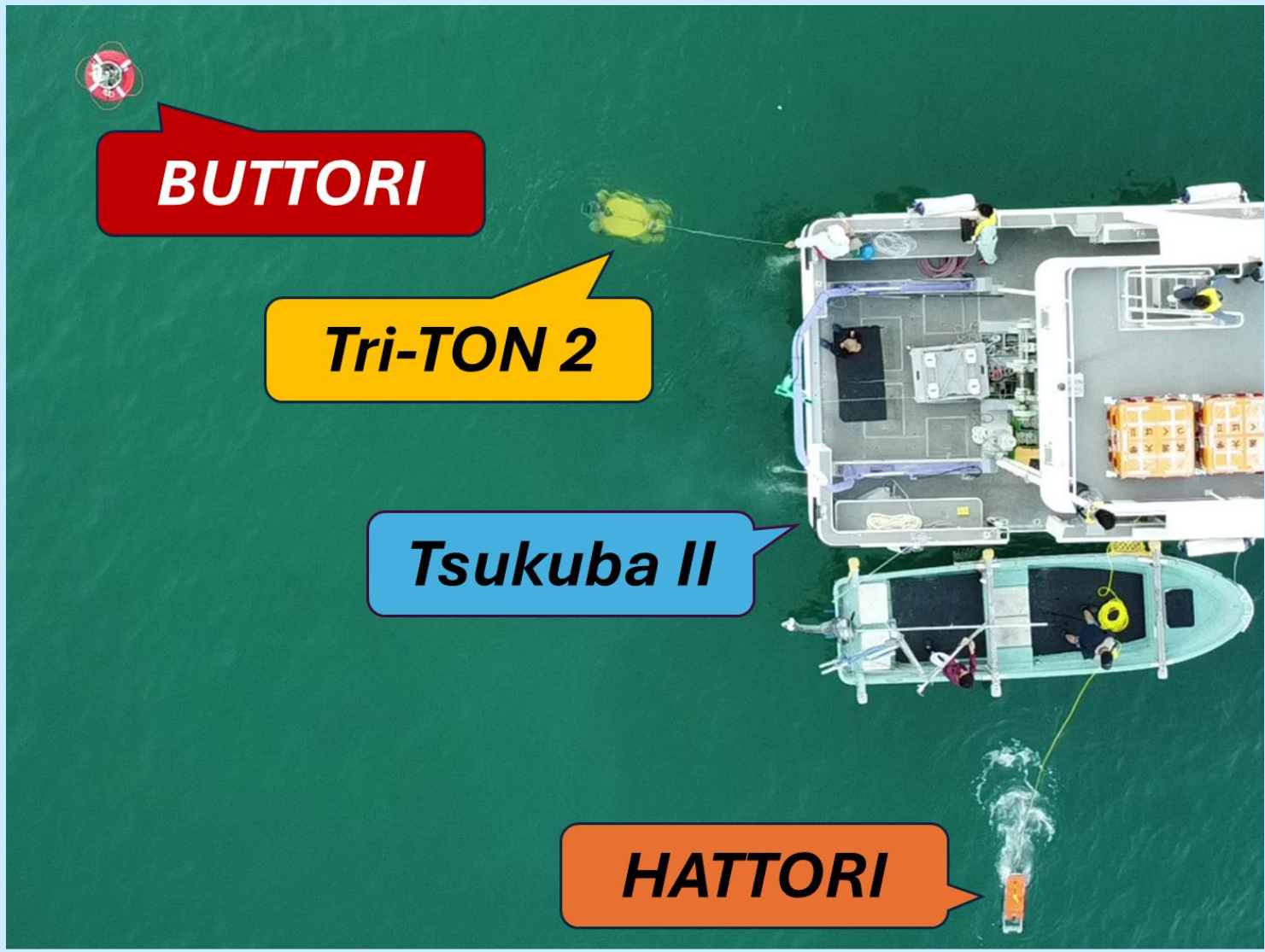
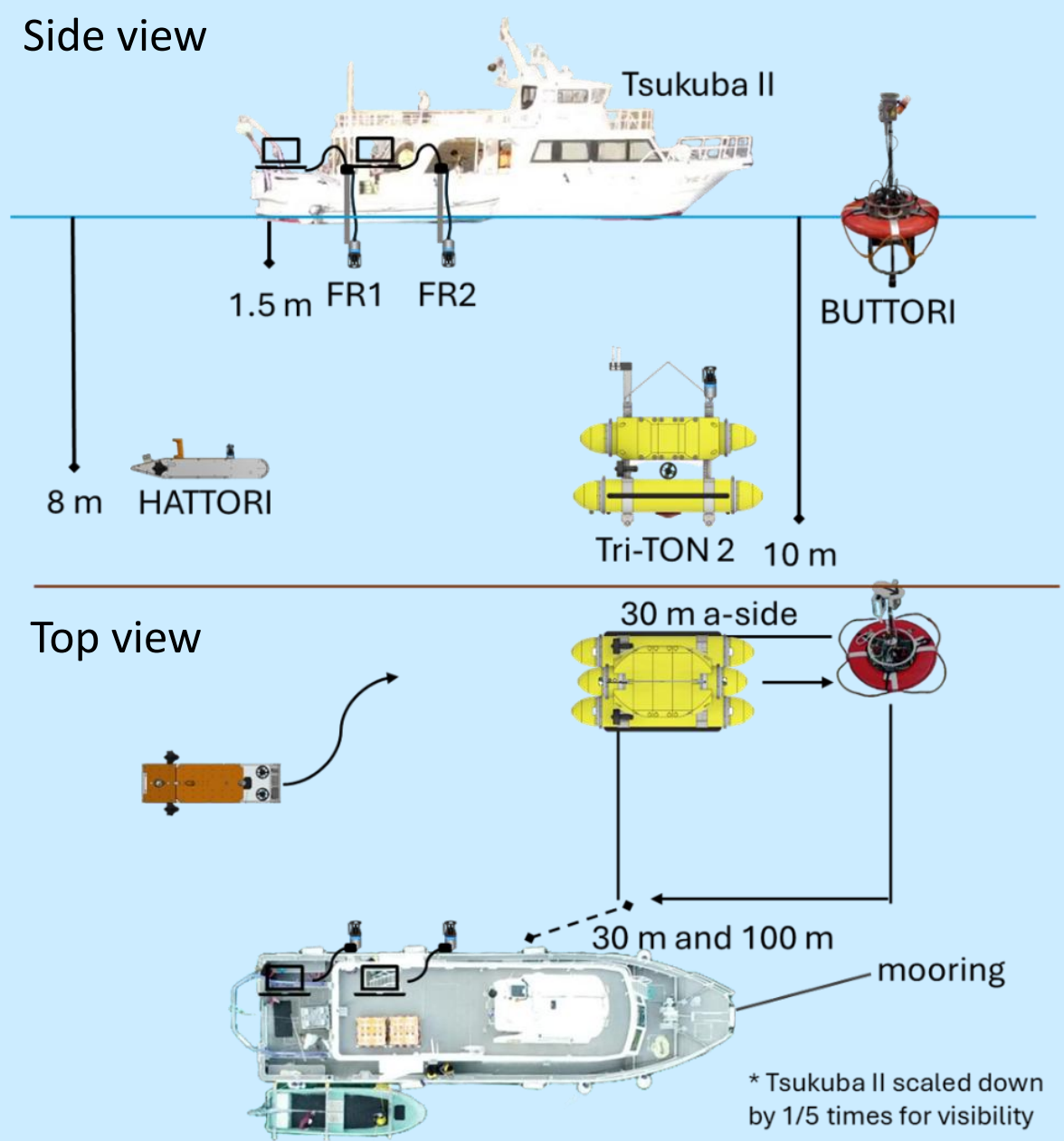
Deployed AUV-ASV in shallow, open-water environments to validate the system and collect real-world data.

@Kobe, Japan AUV seafloor tracking for artificial reef survey

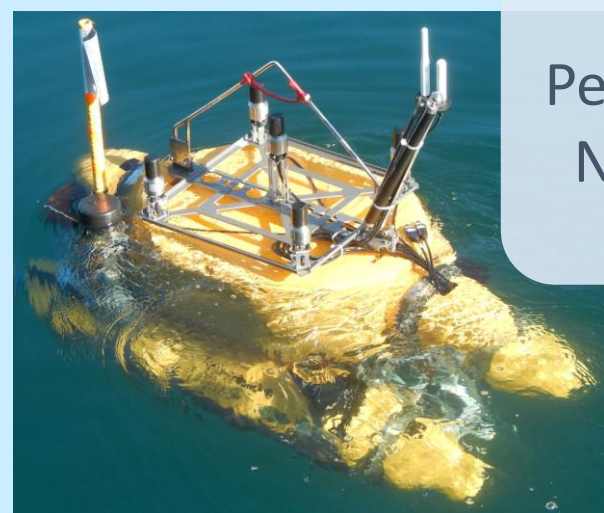


Field trial setup (left), photograph (center), and photogrammetry of the artificial reef (right).

@Shimoda, Japan Multi-AUV acoustic localization field experiment



Field test setup (left) and photograph (right).



High-Performance Navigation Sensors



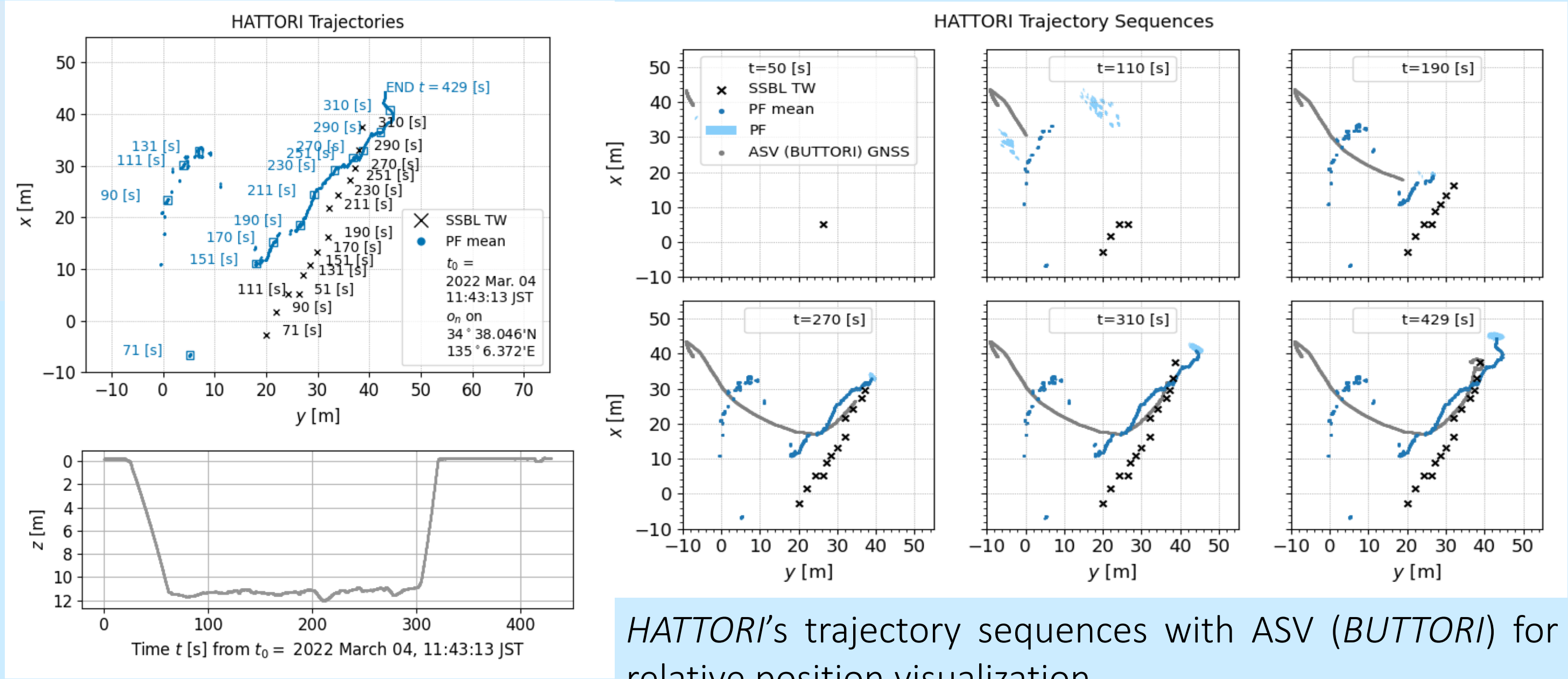
Low-Performance Navigation Sensors

AUV	Tri-TON 2 [3]	AUV	HATTORI [4]
Size	1.41 m × 1.46 m × 0.76 m	Size	1.02 m × 0.48 m × 0.29 m
Mass	260 kg	Mass	18 kg
Max. Speed	0.5 m.s ⁻¹	Max. Speed	2.0 m.s ⁻¹
Max. Depth	2000 m	Max. Depth	300 m
Sensors	Depth: Mensor DPT6000 AHRS: Exail Quadrons DVL: Telydyne RDI Workhorse Navigator SSBL: Blueprint Subsea SeaTrac x150 GNSS: u-blox LEA-6	Sensors	Depth: Blue Robotics Bar 30 IMU: STMicroelectronics LSM9DS1 DVL: WaterLinked DVL A50 (performance) SSBL: Blueprint Subsea SeaTrac x150 GNSS: u-blox UBX-M8030

ASV	BUTTORI [5]
Size	0.8 m × 0.8 m × 1.6 m
Mass	20 kg
Sensors	SSBL: Blueprint Subsea SeaTrac x150 GNSS compass: Hemisphere V104s

RESULTS & DISCUSSIONS

Assessed performance under varying sensor configurations and acoustic observability conditions.

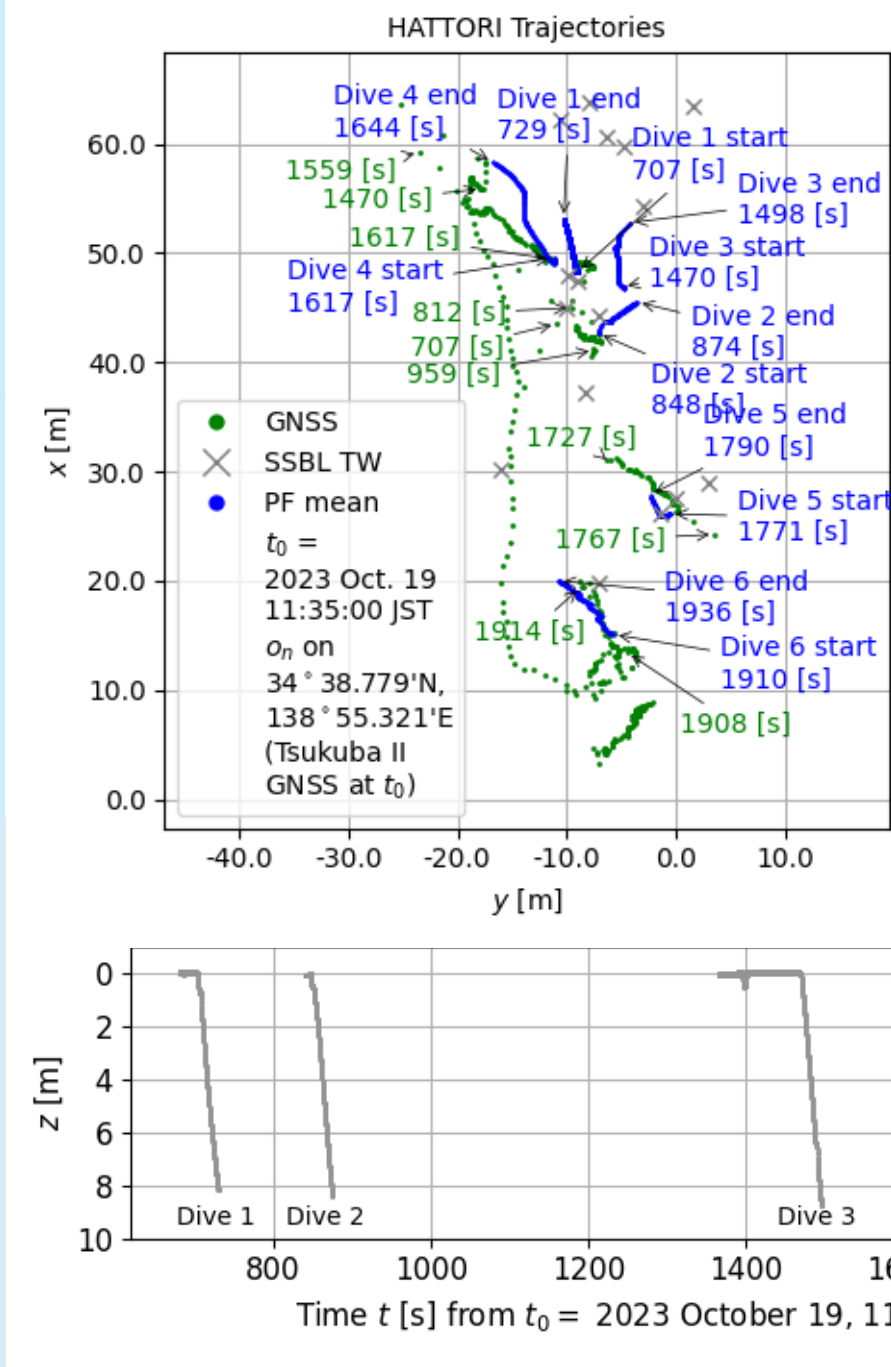


HATTORI's trajectory and depth

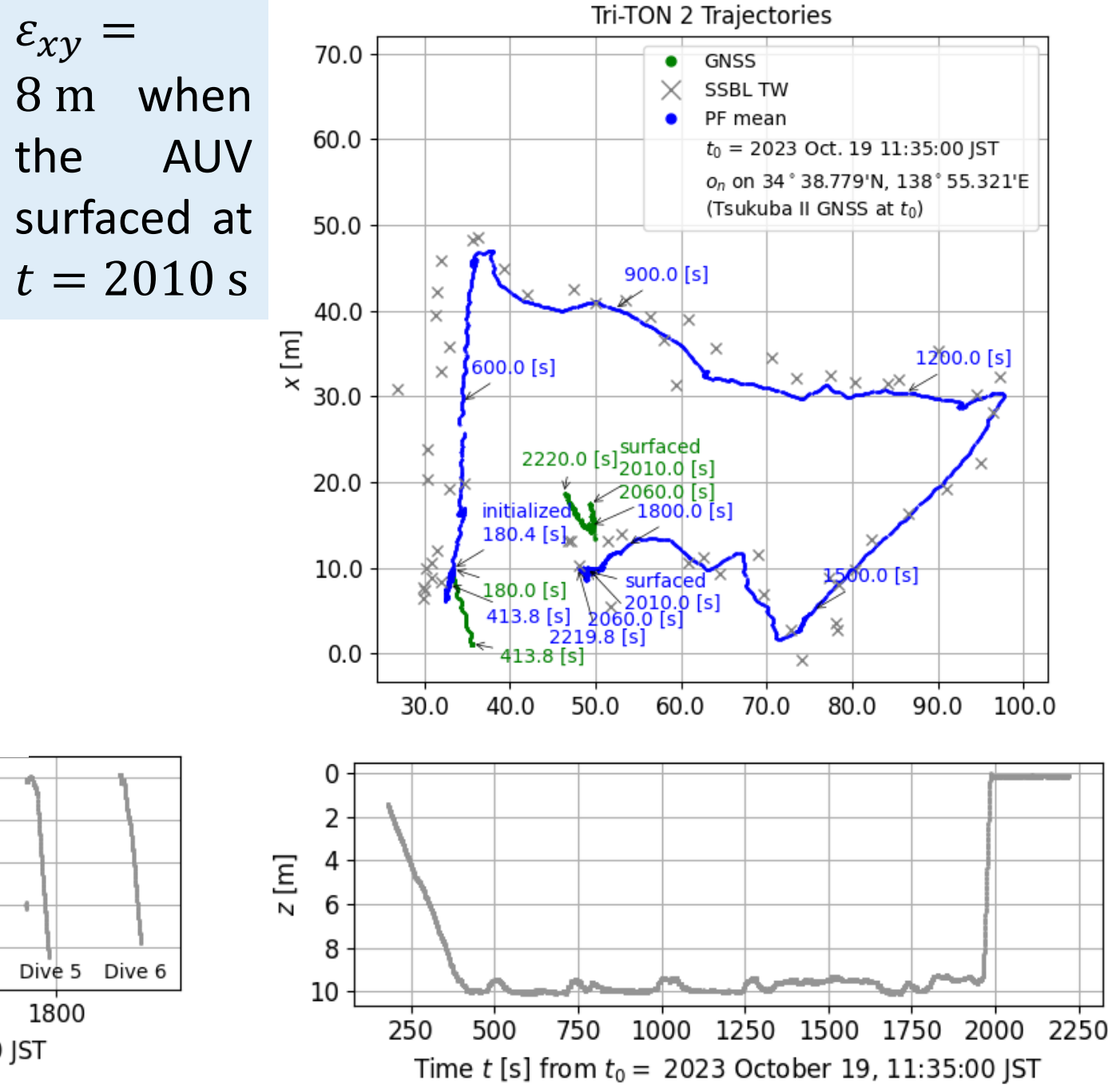
Localization error evaluated against SSBL TW: Kobe field trial

- Proposed PF
 - Statistics: Median ε_{xy} = 6 m (IQR: 5 – 7 m; Range: 4 – 10 m) at t = 210 s
 - Convergence: Suppressed error accumulation during t = 170 – 210 s
- Dead reckoning (DR) baseline (initialized at t = 70 s)
 - Drift: reached ε_{xy} = 6 m after 140 s (at t = 210 s)
 - Divergence: Unbounded error accumulation

Cannot validate the convergence of the PF estimates



HATTORI's trajectory and depth



Tri-TON 2's trajectory and depth

- Adaptive sensor reset enables convergence of PF using BEDD acoustic positioning and ASV position repeat via acoustic communication
- Poor observability combined with large navigation sensor errors causes the estimate to diverge

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- [2] J.-S. Gutmann and D. Fox, "An experimental comparison of localization methods continued," in *IEEE/RSJ International Conference on Intelligent Robots and Systems*, Sep. 2002, pp. 454–459 vol.1.
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- [5] H. Horimoto, S. Tejima, K. Ohkuma, and T. Maki, "Development of autonomous acoustic positioning buoy: -Toward low-cost AUV operation-," in *The Proceedings of JSME annual Conference on Robotics and Mechatronics (Robomec)*, 2021, pp. 1A1-B16.

CONCLUSION

The research proposes a scalable PF self-localization method using the BEDD acoustic positioning for AUV-ASV operations in GNSS-denied and featureless underwater environments. The sea experiment results validate the method. The research contributes towards easily operable multi-AUV-ASV platforms for increased coverage and enhanced mission requirements.

ACKNOWLEDGEMENTS

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