Adaptive Buoyancy Modeling and Float-Time Prediction for a Flooded Aircraft

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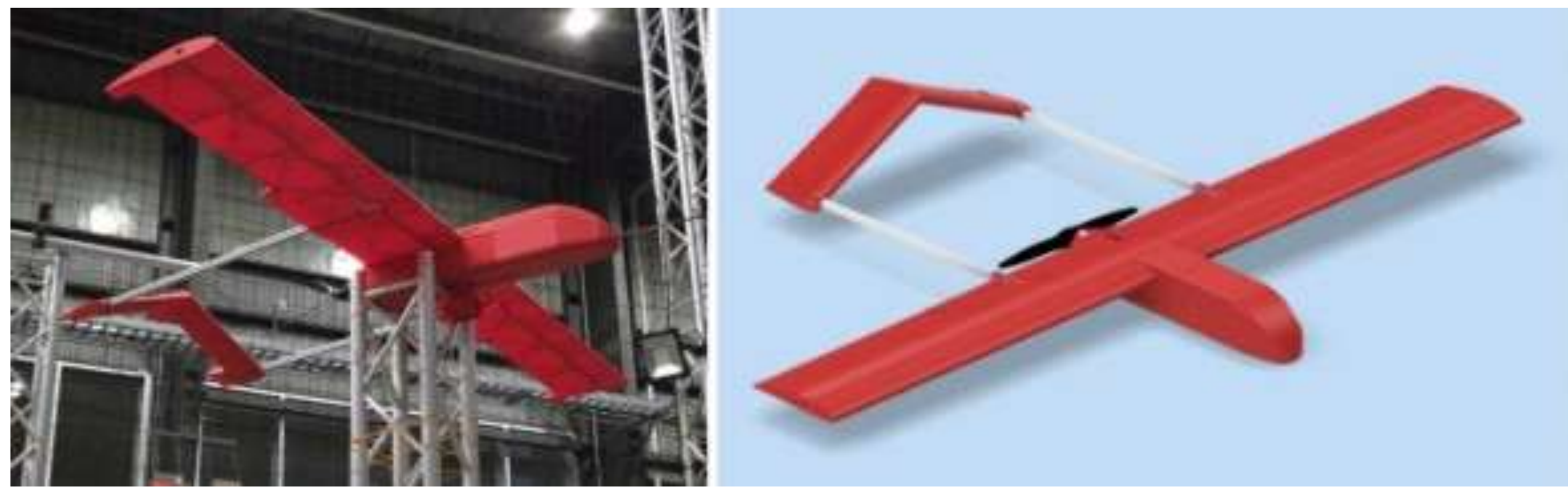
ARTS-Lab
Adaptive Real-Time Systems Laboratory

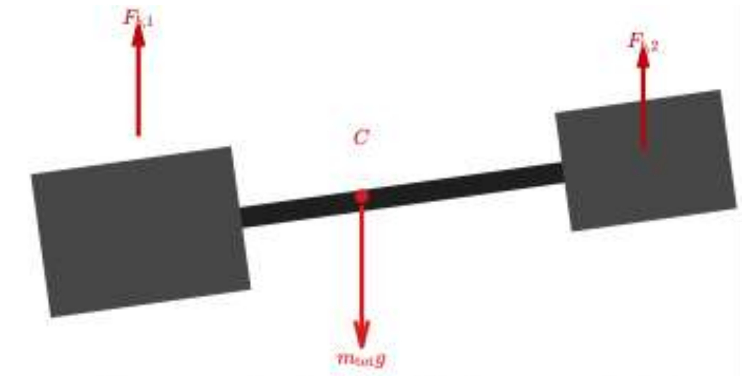
Background

- Aircraft flooding can lead to loss of buoyancy and stability.
- Flooding causes both sinking and rotation as mass distribution changes.
- Developed a physics-based dynamic model to simulate this behavior.
- Evaluated how uncertainty in system parameters affects predicted float time.



Modeling Methodology

- Modeled the aircraft as a rigid body with two flooding tanks.



- Computed the moving center of mass as tank masses increased.

$$x_G = \frac{m_a x_a - m_1 x_1 + m_2 x_2}{m_a + m_1 + m_2}$$

- Calculated buoyant force from submerged tank depth.
- Applied Newton's Second Law for vertical motion.

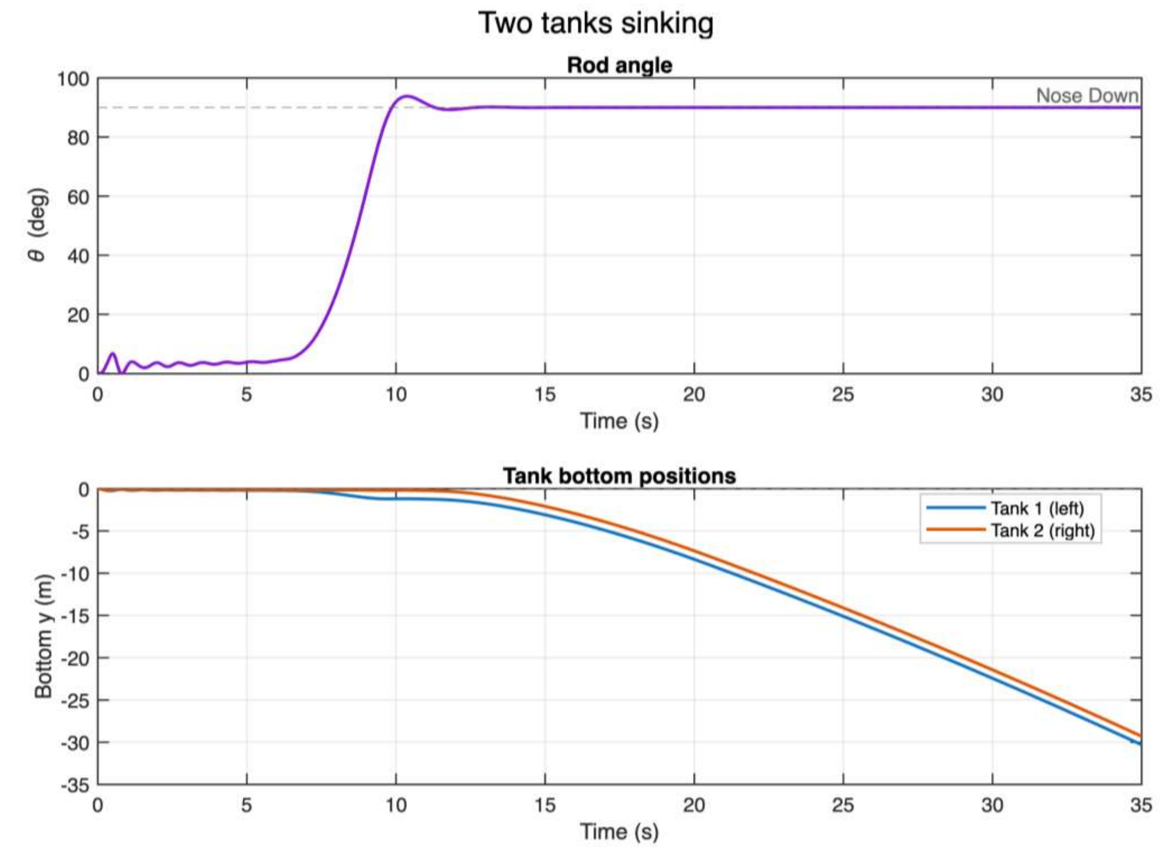
$$\ddot{y}_C = \frac{F_{b,1} + F_{b,2} - m_{\text{tot}} g - c_{y,1}\dot{y}_C - c_{y,2}\dot{y}_C\,|\dot{y}_C|}{m_{\text{tot}}}$$

- Used angular momentum to model aircraft rotation.

$$\ddot{\theta} = \frac{d_1 \cos\theta\, F_{b,1} + d_2 \cos\theta\, F_{b,2} - c_{\theta,1}\dot{\theta} - c_{\theta,2}\dot{\theta}\left|\dot{\theta}\right| - \dot{I}\,\dot{\theta}}{I_a + m_a d_a^2 + m_1 d_1^2 + m_2 d_2^2}$$

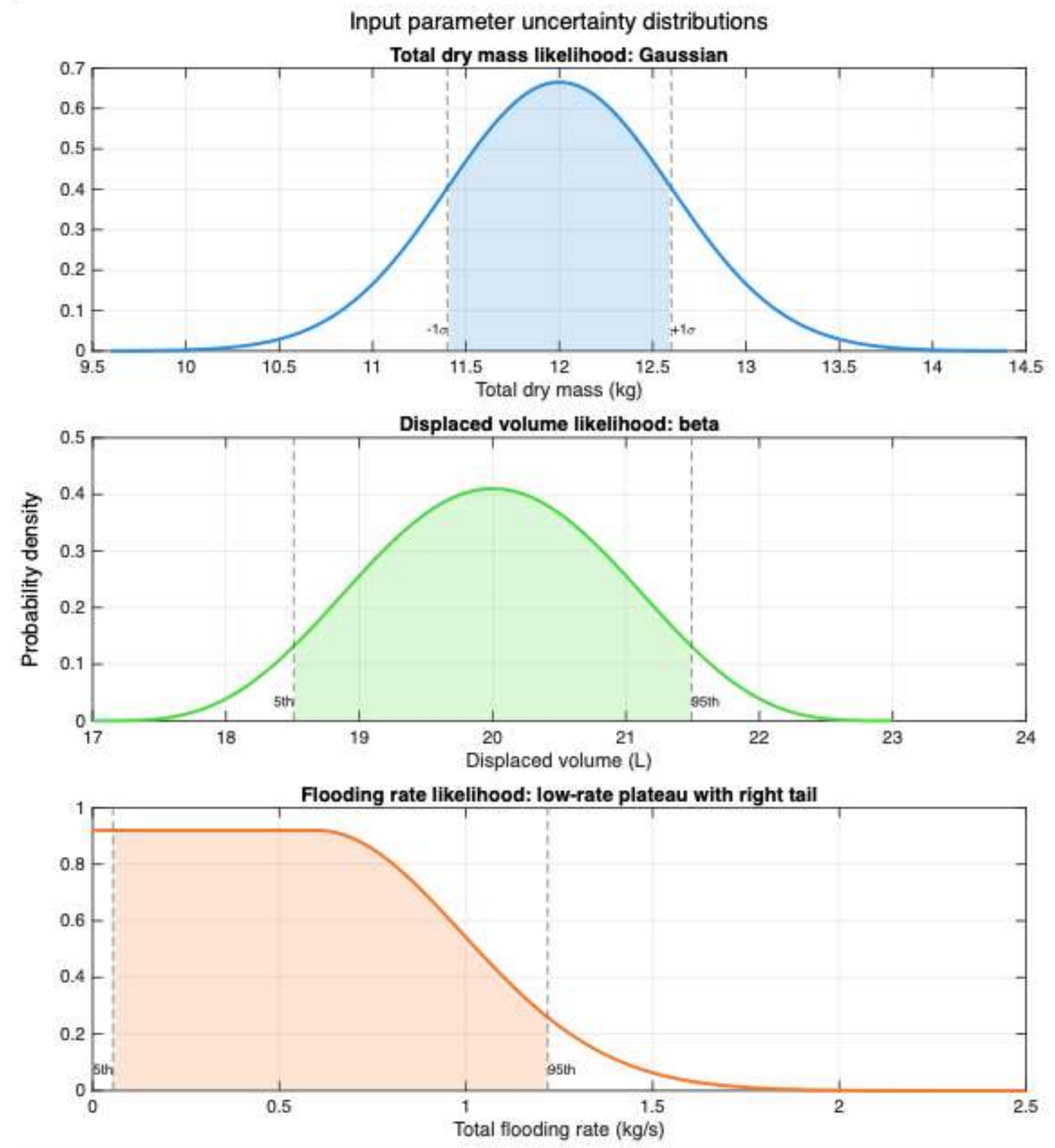
- Included changing moment of inertia and hydrodynamic damping.
- Simulated the system in MATLAB using semi-implicit Euler integration.

Simulation Results

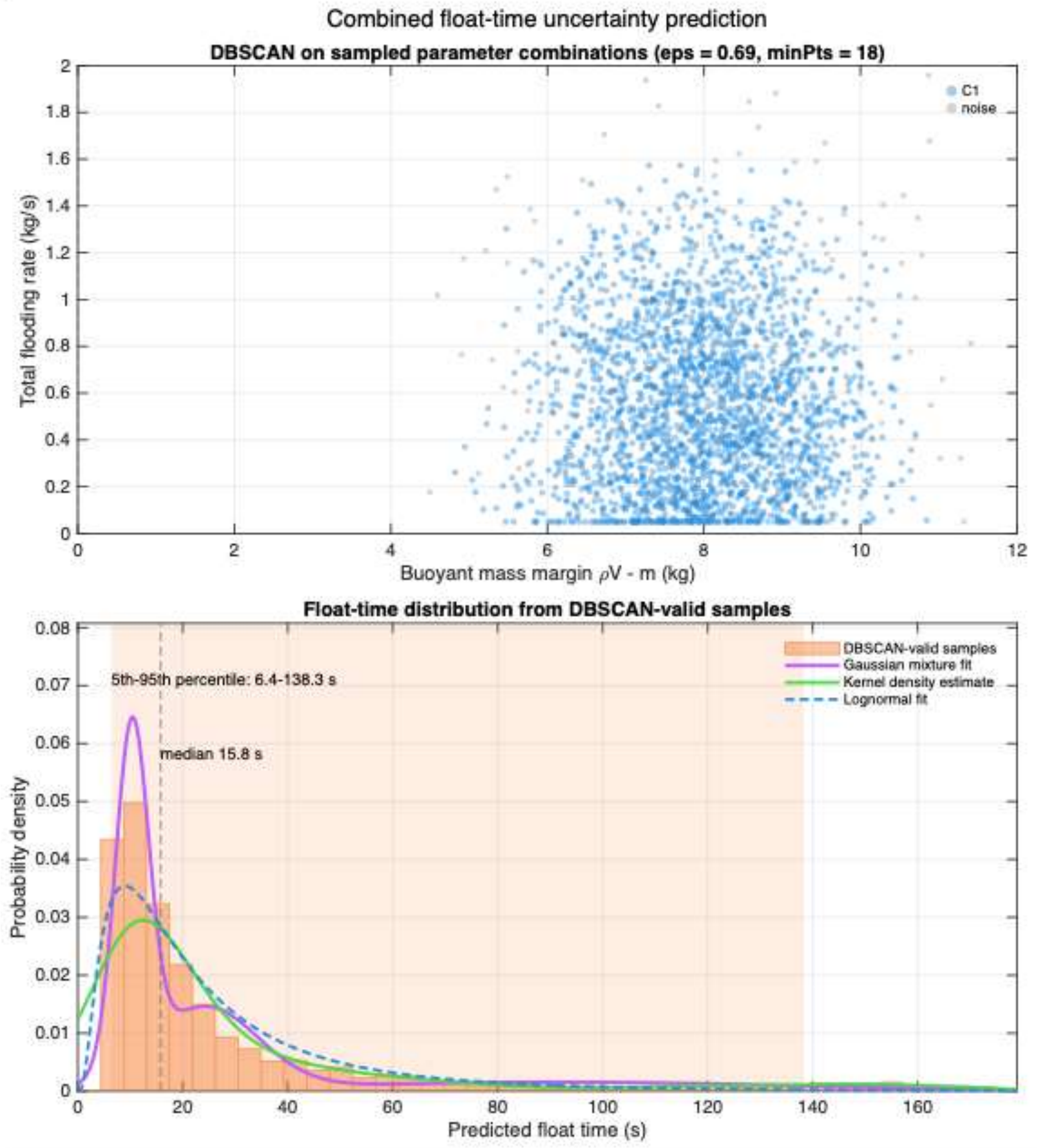


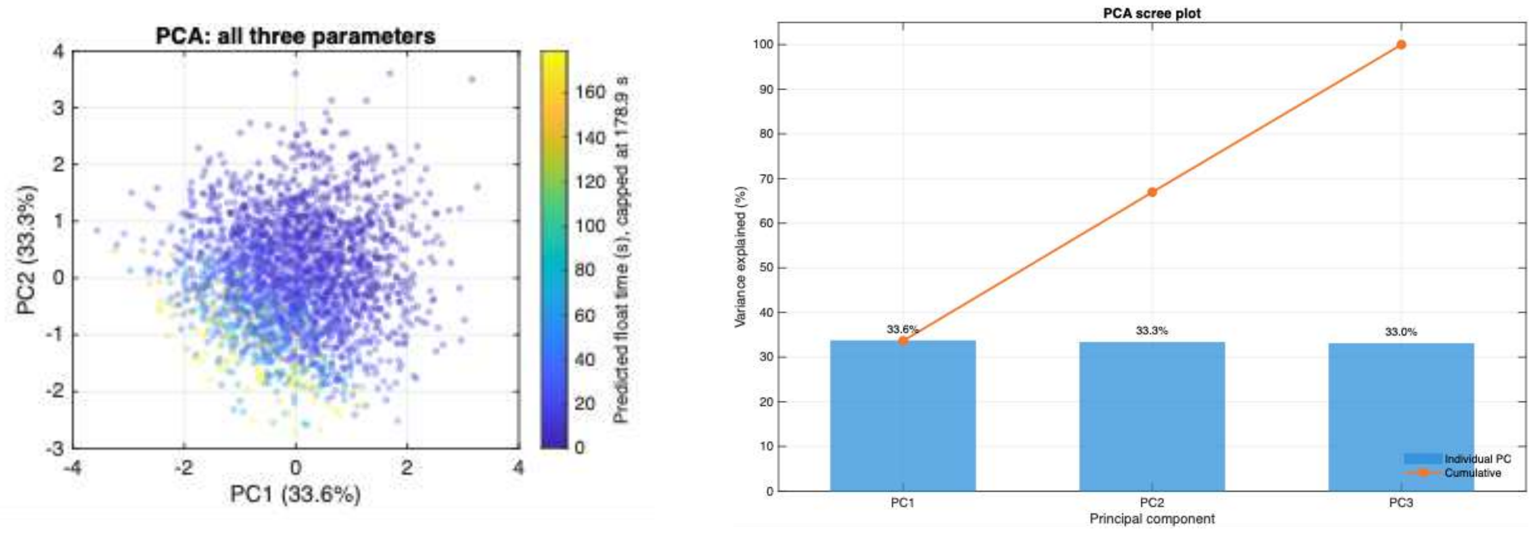
Uncertainty Analysis

- Considered uncertainty in: Dry aircraft mass, volume, and flooding rate
- Generated 20,000 Monte Carlo simulations. Applied DBSCAN to identify the most likely parameter combinations. Predicted a median float time of 15.8 s. Estimated a 5th–95th percentile range of 6.4–138.3 s. Flooding rate had the strongest effect on predicted float time.



Uncertainty Analysis





Future Work

- Include fuselage buoyancy.
- Model flooding based on hole geometry and pressure.
- Incorporate wave and current effects.
- Validate against experimental or real-world data.

References

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[2] Y. Zhao, P. Liu, and Q. Qu, "Estimation of Static and Dynamic Floatation Characteristics During Aircraft Ditching," in Proceedings of the 33rd Congress of the International Council of the Aeronautical Sciences (ICAS), 2020.
[3] W. Luo, W. Gu, Y. Huang, and L. Chang, "Experimental Investigation of Dynamic Characteristic During Civil Aircraft Ditching," Chinese Journal of Aeronautics, vol. 38, no. 5, 2025.

This material is partially supported by the National Science Foundation (NSF) grant number CPS - 2237696. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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