**Assumption  
Environmental Conditions**

1. The acoustic properties of the water body (pool, lake) are assumed to be stable, with variations in temperature, salinity, and depth having a negligible or compensable effect on ultrasonic signal propagation.

2. Background noise from water flow, vessels, or other sonar systems is assumed not to significantly interfere with the reception of beacon signals, or its effects can be mitigated through signal processing (e.g., filtering techniques).

3. The impact of sound speed stratification on ranging accuracy is assumed to be within an acceptable range and will not introduce significant errors in distance estimation.

4. The beacons and boat remain stable during testing, with no significant displacement or orientation changes that would impact the measurement accuracy.

**Hardware Capabilities**

1. The existing single-beacon ranging system can be extended to a three-beacon system without requiring major modifications to the core hardware.

2. The ultrasonic transducers operate reliably within the designated frequency range with sufficient transmission power and reception sensitivity.

3. The RTK-GPS and IMU provide sufficiently accurate positioning and orientation data, with errors within an acceptable range for subsequent SLAM applications.

4. The microprocessor has adequate computational power and I/O bandwidth to process multi-beacon signals in real time, including FFT-based signal separation and time synchronization.

5. The ADC (Analog-to-Digital Converter) has a sufficient sampling rate and resolution to accurately capture and process the received sonar signals.

6. The system meets the minimum data acquisition rate of 1Hz.

**Experimental error and System Extensibility**

1. The ranging accuracy is expected to be within an acceptable error margin, accounting for minor variations due to noise and environmental factors.

2. The system is scalable for future expansion to more than three beacons, although this study focuses on a three-beacon setup.

**Deliverables**

Development and Implementation of the Multi-Beacon Ranging System

1. Upgrade the existing single-beacon sonar system to support simultaneous ranging of three beacons, ensuring measurement accuracy meets experimental requirements.
2. Implement Frequency Division Multiple Access (FDMA), assigning distinct ultrasonic frequencies to each beacon to prevent signal interference and improve stability.
3. Develop and integrate a real-time signal processing algorithm on the microprocessor, including FFT-based spectral analysis or band-pass filtering, to separate and decode different frequency signals.

Real-Time Data Acquisition and Fusion System

1. Build a complete data acquisition system capable of collecting and storing sonar ranging data, RTK-GPS positioning data, and IMU orientation data in real time.
2. Ensure a minimum sampling frequency of 1Hz, guaranteeing the system collects at least one full set of ranging data per second to prevent data loss or timing inconsistencies.
3. Implement a high-precision time synchronization mechanism to ensure strict alignment of sonar, GPS, and IMU data, meeting the requirements for subsequent 3D SLAM research.

Experimental Validation and System Performance Assessment

1. Conduct controlled experiments in test environments to validate system performance, measuring ranging accuracy, signal stability, and the impact of external noise.
2. Evaluate system robustness by recording errors in different experimental conditions, including varying beacon distances and water flow conditions.
3. Generate a comprehensive experiment report detailing system accuracy, error analysis, signal interference impact, and optimization recommendations.

Research Dataset

1. Collect and structure a dataset consisting of sonar ranging measurements, GPS trajectory data, and IMU orientation data to support 3D underwater SLAM research.
2. Include diverse experimental conditions (varying beacon distances, water flow influences, and different sampling rates) to ensure dataset versatility and applicability.

Technical Documentation and Code Deliverables

1. System architecture overview (ranging methodology, data flow, time synchronization mechanism).
2. Details of ranging algorithm implementation (FFT processing, Time of Flight calculation, error compensation).
3. Data acquisition and storage framework (sensor data synchronization, dataset structure).
4. Deliver a fully documented code repository including microprocessor firmware, data acquisition and detailed code comments.