BlueTrace: Marine Microplastic Tracker

Group 32 – Project Final Summary

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Project Requirements:

The Design section defines the system's design goals, analyzes the current workflow, proposes a new architecture, and decomposes the system into subsystems, classes, and data flows. This section ensures the platform's scientific reliability, maintainability, and long-term extensibility while supporting fast visualization, reproducible analysis, and secure collaboration across institutions.

Design Goals:

The design prioritizes **clarity**, **robust data validation**, **modular subsystems**, and **low-latency map interaction**. It emphasizes containerization, reproducibility, and a clean 2D mapping workflow that remains performant even with large regional datasets. The architecture supports progressive enhancement toward future 3D features and advanced modeling while maintaining a stable MVP foundation.

Current System Design:

The current ecosystem for oceanographic work is fragmented across GIS tools, notebooks, and manual map exports. Existing workflows lack automated validation, standardized filters, consistent timeline playback, or reproducible summaries. Analysts manually stitch together NetCDF, GeoJSON, and CSV data, often with inconsistent preprocessing. The current design section documents these gaps to justify the more integrated architecture proposed for *BlueTrace*.

Proposed System Design:

BlueTrace introduces a unified, cloud-ready architecture that integrates dataset ingestion, validation, visualization, and reporting into a coherent user workflow.

Class Identification & Dynamic Modeling:

The design identifies key domain objects: **Dataset**, **Region**, **Measurement**, **TrackPoint**, **SensorStation**, **UserSession**, and **ProvenanceRecord**. These domain objects specify how they interact across ingestion, map rendering, filtering, and reporting.

System Archiecture:

BlueTrace adopts a layered architecture with clean separation of concerns:

- **Data Management & Validation Layer:** Handles ingestion, CRS checks, metadata extraction, QA flags, and provenance.
- **Machine Learning & Prediction Layer**: Supports basic trend-based projection and prepares the foundation for future advanced models.

- **Visualization & UI Layer:** Renders 2D maps, overlays, filters, legends, and timeline playback with emphasis on responsiveness.
- **Session Control & Export Layer:** Stores user state, manages summary generation, and handles export pipelines.
- **Reporting Layer**: Produces structured summaries, snapshots, and reproducible artifacts for collaboration.

Subsystem Decomposition

The proposed architecture divides the system into five major subsystems:

1. **Data Management & Validation**
2. **Machine Learning & Projection**
3. **Visualization & User Interaction**
4. **Session Control & Export**
5. **Reporting**

Final System Design:

The final design includes full UML diagrams showing:

- class relationships (Dataset, Region, Measurement, TrackPoint, SensorReading, etc.)
- subsystem interfaces
- data flow across ingestion → validation → visualization → export
- detailed package layouts

This architecture supports all functional and non-functional requirements while providing a stable foundation for future enhancements such as deeper ML modeling, 3D ocean layers, realtime sensor feeds, and mobile citizen-science extensions.

Conclusion:

The Design section establishes a robust, modular foundation for *BlueTrace*, ensuring that scientific integrity, responsive visualization, and secure data handling are supported at every architectural layer. By defining clear subsystem boundaries, prioritizing reproducibility and performance, and aligning UI, data flow, and validation processes with stakeholder needs, the design positions *BlueTrace* for long-term reliability and future expansion. This architecture not only meets the immediate requirements of dataset ingestion, map exploration, area inspection, and simple projection but also provides a scalable pathway for advanced modeling, richer interfaces, and broader regional integration across ocean health initiatives.