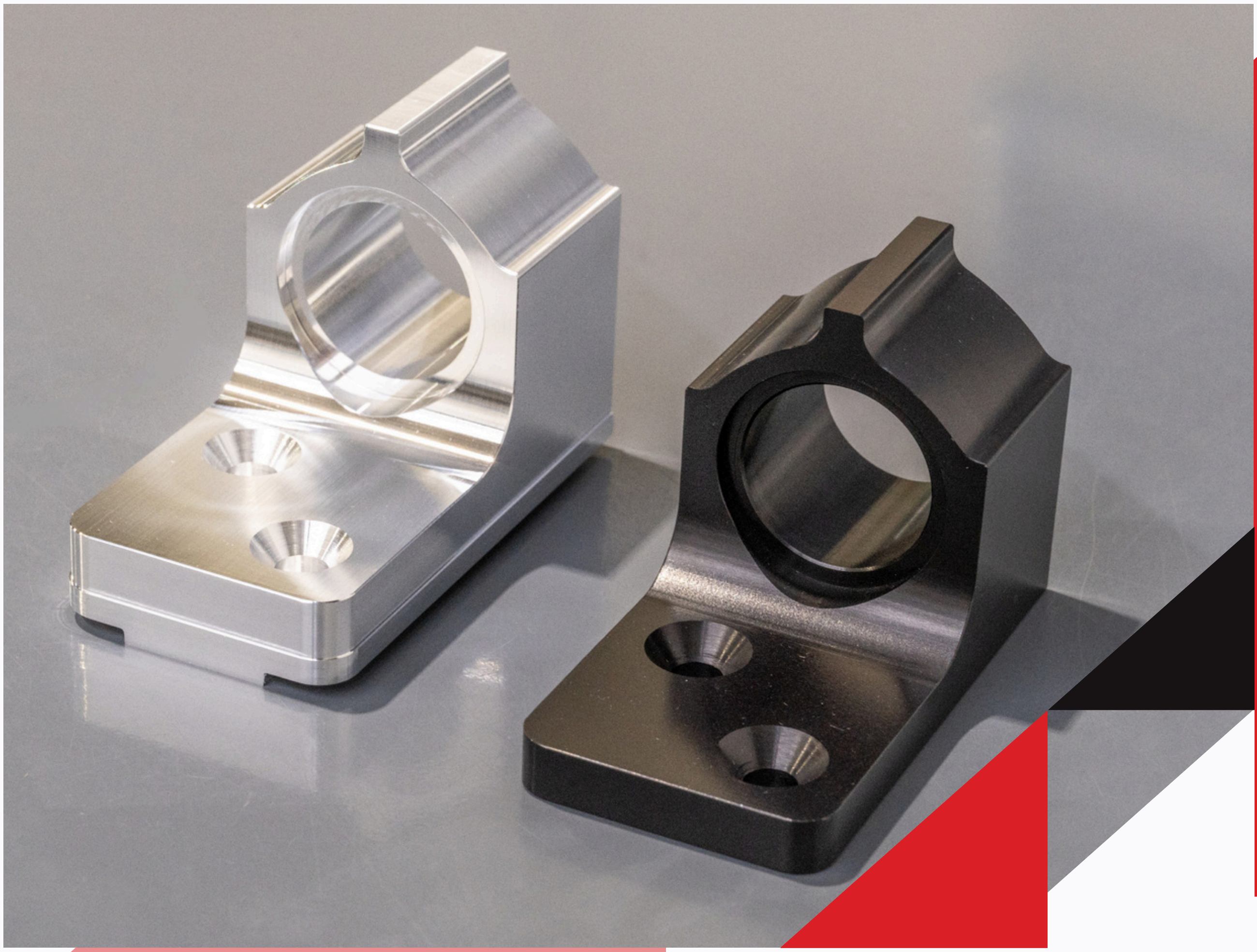
KL ENGINEERING

CASE STUDY:

RAPID PILOT-TO-PRODUCTION TRANSITION FOR A MARINE MECHANISM INTEGRATED ASSEMBLY



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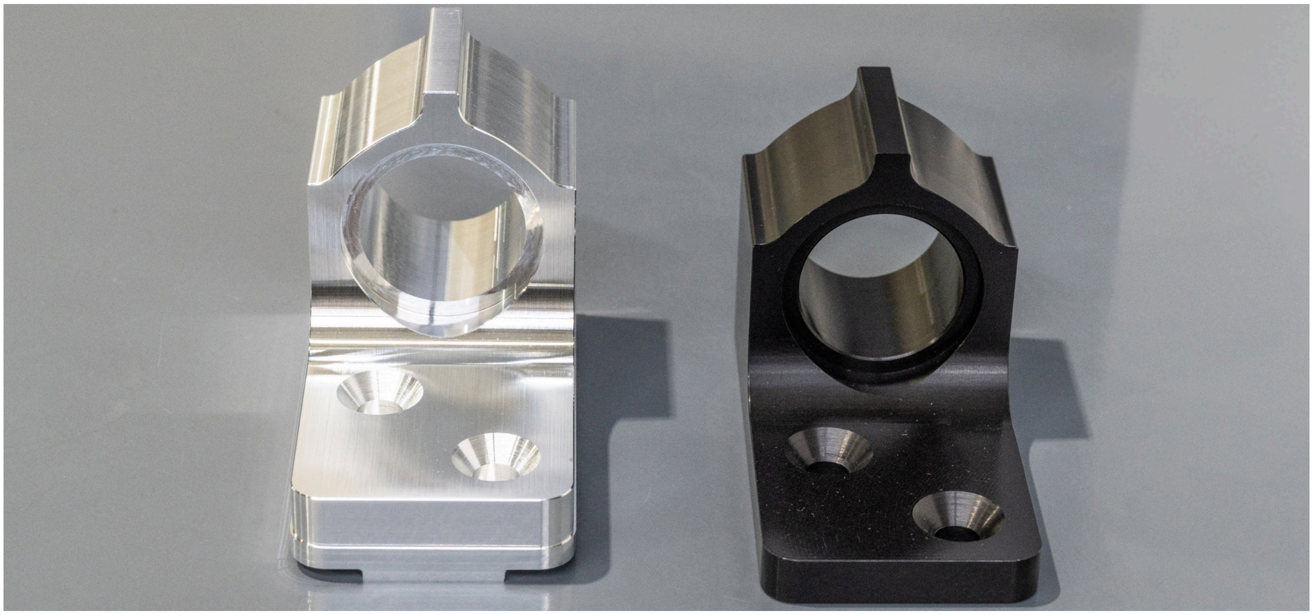


KL Engineering, Inc. was approached by a customer who needed to rapidly scale from a single in-house lab proof-of-concept to production-ready, field-shippable integrated assemblies for a marine mechanism. The assemblies had to be reliable in a salt-spray environment with wetting cycles and rotary motion occurring within sealed and semi-sealed subsystems. However, the transition effort faced practical constraints: the initial sample size was small, and the customer needed to be confident that the performance validated in the lab could be replicated in production and verified during offshore testing.

This created two core challenges. First, the integrated design had to be manufactured with sufficient repeatability to preserve functional performance – especially at critical fit interfaces such as bearing housing features and other alignment-sensitive interfaces – so that assembly-to-assembly tolerance variation did not erode the mechanism's operation. Second, the customer needed robust long-term marine reliability without relying on extensive re-prototyping, which required a system-level approach to materials, coatings, hardware selection, and isolation layers to prevent corrosion and mitigate galvanic interactions between adjacent components.

In addition, because essentially no production verification documentation or characterization/diagnostic framework existed for this specific electromechanical assembly, the customer required a manufacturable and testable production package: consistent assembly processes, assembly-level diagnostic testing to detect potential issues before shipment, and clear documentation artifacts that would store and communicate test outcomes for each delivered assembly under a single purchase-order model.

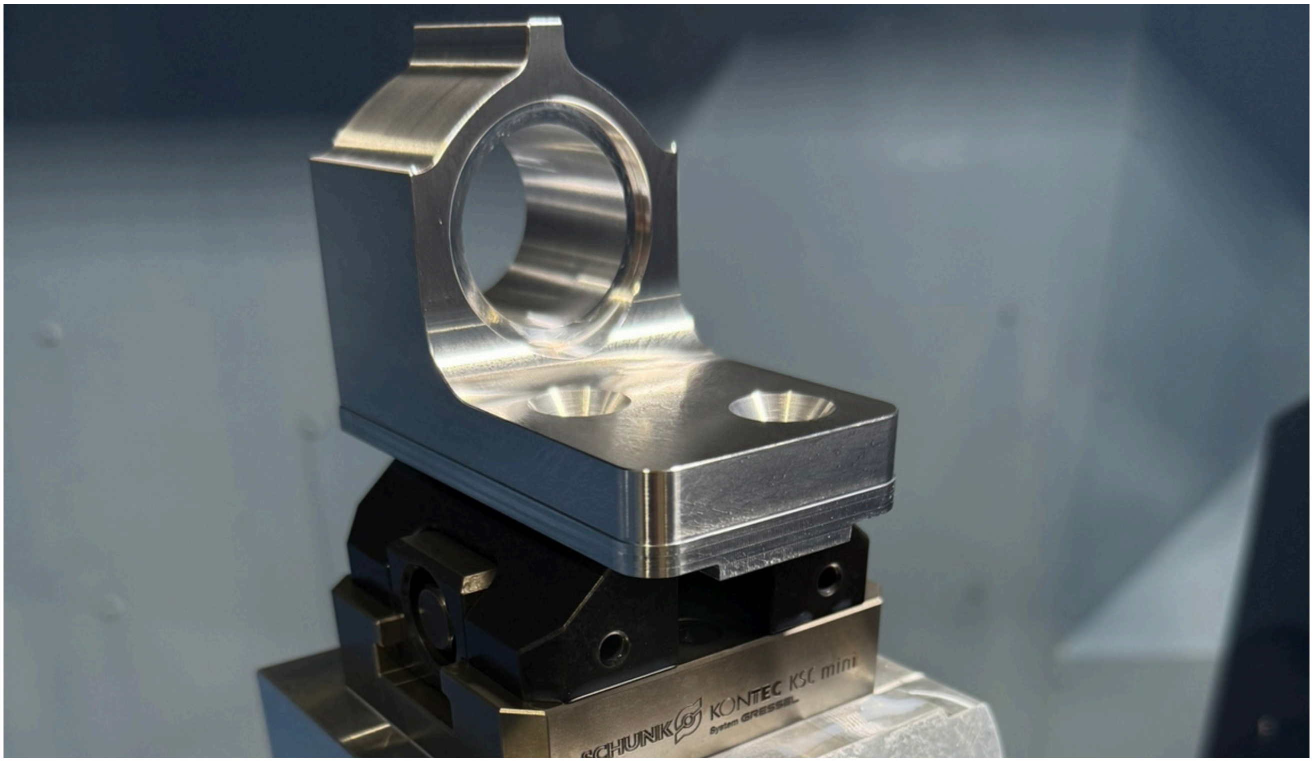
Program Background and Functional Scope

The integrated assembly consisted of a multi-part mechanical substructure, electromechanical and commercial components (including stepper motors), and a sealed electrical enclosure. The mechanical portion incorporated bearing housings as key structural and alignment features. In the delivered assembly configuration, four bearing housings were included, along with multiple additional machined parts and commercial components.

The customer’s internal proof of concept demonstrated feasibility at both conceptual and functional levels (i.e., the mechanism operated as intended under lab conditions). The customer then needed to launch pilot production to support offshore testing overseas quickly, where assemblies would operate in a marine environment that was not fully submerged but would experience:

- salt spray and wetting,
- exposure to conductive contaminants and marine atmospheric salts,
- corrosion risks at interfaces between dissimilar metals,
- functional reliability across moving rotary components operating within the integrated system.

KL Engineering’s role was to transform the conceptual design into a scalable, repeatable manufacturing and verification process – so that performance observed in the lab could be replicated reliably at production scale in the field.



Engineering Objectives

The program had several tightly coupled objectives:

1. Manufacturability and scalability under constrained sampling
    - a) Transition quickly from prototype to pilot production with a limited ability to iterate via extensive prototype runs.
    - b) Establish repeatable processes with predictable outcomes before shipment.
2. Maintaining functional tolerances at critical interfaces
    - a) Improve handling and reduce variability to support repeatable feature tolerances.
    - b) Control bearing-related fits (notably bore interface features of the bearing housing) to preserve alignment and operating life.
3. Marine reliability through system-level material compatibility
    - a) Address corrosion mechanisms driven by galvanic coupling and salt exposure.
    - b) Select and qualify a coordinated "materials and coatings stack" across adjacent components, including:
        - i. machine part materials,
        - ii. hardware material selections,
        - iii. coating systems,
        - iv. gasketing materials,
        - v. isolation layers/interstitial layers intended to reduce electrochemical interactions.
4. Assembly-level verification and diagnostic capability
    - a) Develop characterization fixtures, assembly processes, and diagnostic tests required to detect potential issues before shipment.
    - b) Create documentation that defines how test results will be captured, interpreted, and stored to ensure traceability.
5. Single point of contact and integrated delivery
    - a) Support the customer with one purchase order covering completed integrated assemblies.
    - b) Operate with a collaborative cadence enabled by close geographic proximity to the customer for on-site input during build and validation checkpoints.

Technical Approach

1.) Bearing housing and interface design for manufacturing revisions

Although the bearing housing was a component of a larger integrated assembly, it served as a critical functional interface for alignment and load transfer in the mechanism. KL Engineering and the customer's engineering team focused on targeted revisions to improve manufacturing repeatability and reduce tolerance stack-up risk.

Key manufacturing-oriented actions included:

- Feature and mounting changes to reduce handling complexity and variability during assembly.
- Improvements to the machining/fixturing strategy (implicitly tied to reduced part handling) to enhance the stability of bearing-fit interfaces.
- Tight control of bearing fits in the bearing housing bore interface, ensuring that the mechanical fit relationships between housing and mating bearing components remained consistent across production units.

The intent was not merely to “make the part,” but to ensure that the part’s functional interfaces would support repeatable performance across an assembly-level test campaign.

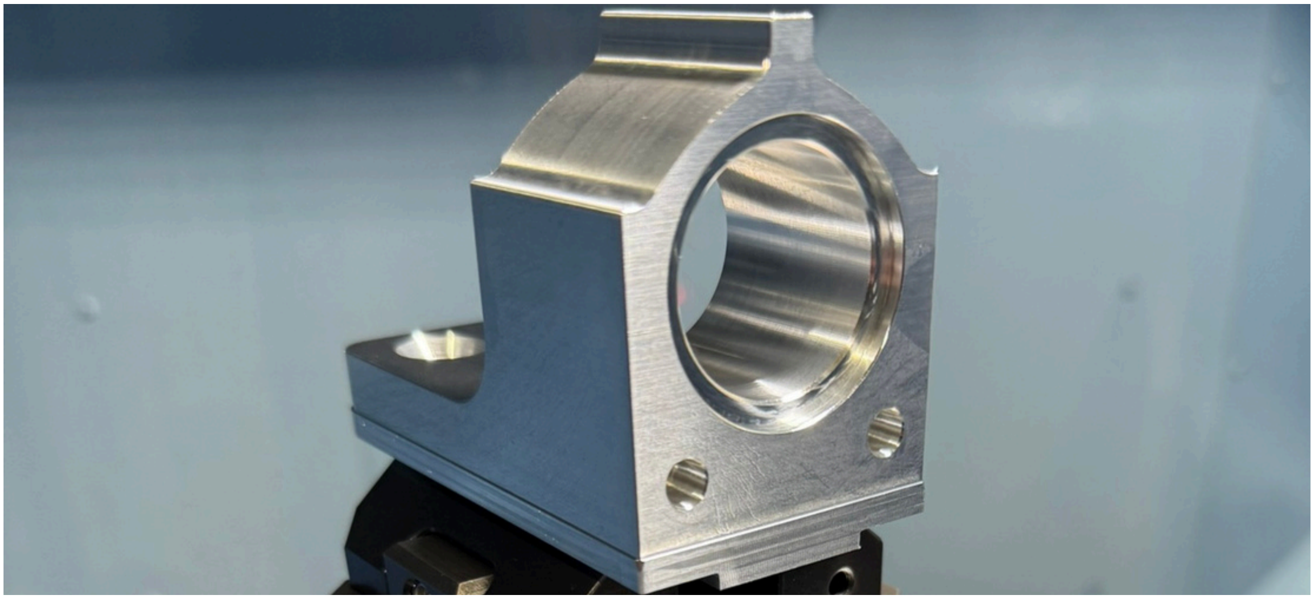
2.) Integrated marine corrosion control: materials, coatings, and isolation strategy

A principal challenge of the program was marine environmental survivability, not primarily in machining difficulty, but in ensuring the long-term reliability of the assembled system under salt-spray exposure.

KL Engineering coordinated corrosion mitigation across the full assembly system stack, including:

- material selection for adjacent components to prevent galvanic corrosion,
- hardware selection and compatible coatings to reduce electrochemical incompatibility,
- coatings on machine hardware where relevant,
- gasketing and isolation layer selection to limit contact between dissimilar metals and reduce pathways for salt-driven degradation.

Since the program transitioned rapidly from a lab prototype to pilot production, KL Engineering and the customer had limited opportunities to validate every combination through extensive experimental prototype builds. Instead, they pursued a disciplined, upfront selection strategy, leveraging established material compatibility principles and implementing an integrated “togetherness” approach: adjacent materials were evaluated as an assembly system rather than as isolated parts.



3.) System-level verification: diagnostic tests and characterization fixtures

Given the complexity of the integrated mechanism – electronics, motors, rotary motion, and sealed electrical enclosure – the program required diagnostic readiness at the assembly level. Critically, documentation and test-definition artifacts did not exist before the transition effort, so we had to create a verification backbone for production shipments.

KL Engineering developed:

- characterization fixtures to enable consistent measurement and validation of assembly performance,
- assembly processes aligned with repeatability requirements (including the bearing housing interface and corrosion-control stack),
- diagnostic test procedures designed to catch potential problems before units are shipped to the field,
- a documentation framework defining how test results would be captured and stored, creating a single traceability path for a customer purchase order that covered completed assemblies.

The diagnostic strategy addressed the reality that the customer was relying on lab-proven behavior but needed confidence that production builds would match that performance in the marine environment.

Manufacturing and Project Execution Model

Collaborative pilot-to-production cadence

The customer had an operational presence close enough to KL Engineering that customer representatives could be on-site during key build stages. This enabled:

- rapid resolution of feature questions,
- immediate validation checkpoints during assembly build,
- faster iteration on manufacturability issues that would otherwise be slowed by remote review cycles.

This on-site collaboration was instrumental in closing the gap between conceptual prototype design and production-ready execution under time constraints tied to overseas offshore testing.

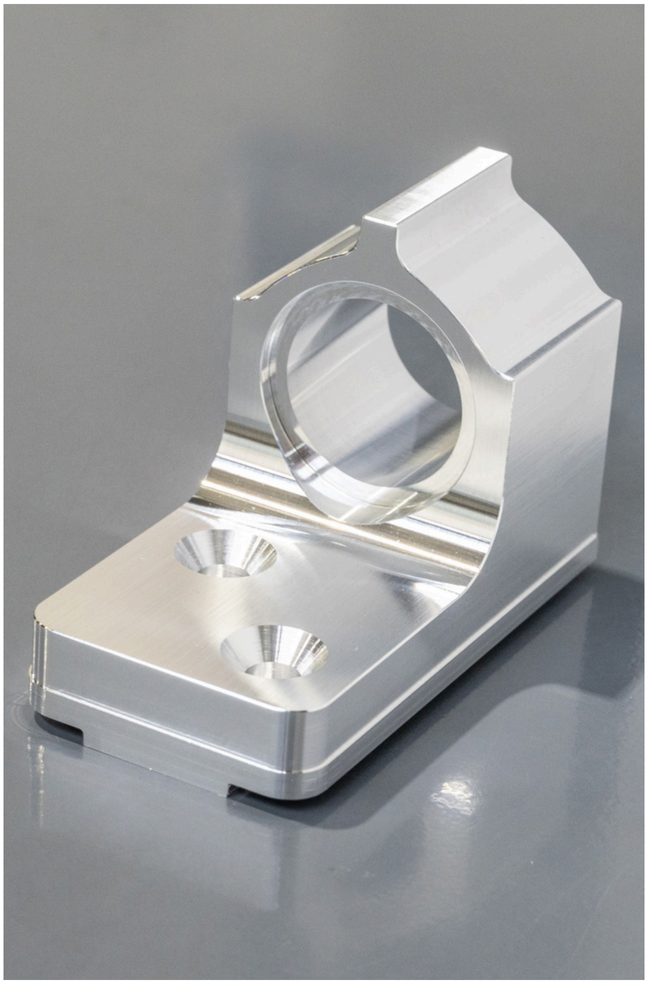
Single purchase order integrated delivery

Rather than delivering parts in a fragmented supply model, the customer issued a purchase order for completed integrated assemblies. KL Engineering, therefore, functioned as a comprehensive manufacturing and verification partner – requiring internal process maturity across machining integration, component kitting, assembly, testing, and documentation.

Outcome and Impact

By combining manufacturability revisions (including bearing housing interface and mounting changes), system-level marine corrosion control (materials, coatings, gasketing, and isolation layers), and newly developed characterization fixtures and diagnostic tests, KL Engineering enabled the customer to:

- transition from lab proof concept to field-suitable production assemblies quickly,
- ship multiple integrated assemblies overseas for offshore testing,
- maintain confidence that field units would replicate lab-observed performance,
- implement assembly-level testing and traceability despite the absence of prior program documentation.



Conclusion

1. In marine electromechanical systems, corrosion reliability is an assembly-level problem. Treating parts as standalone units increases risk; adjacent material compatibility and isolation strategy must be engineered as a coordinated stack.
2. Tolerances and repeatability depend on how parts are handled and mounted, not only on the toolpath and nominal dimensions. Reducing handling variability can directly improve the reproducibility of functional fit across production units.
3. When documentation and test strategies do not exist, diagnostic capability becomes a first-order manufacturing deliverable. The ability to characterize and detect issues before shipment is essential when sample sizes are small and iteration cycles are constrained.