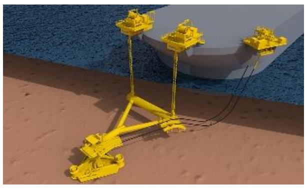
SWIM JIP,

Shallow Water Innovative Mooring

Project Plan (Rev. 1.1, August 2026)

The SWIM JIP seeks to establish a shared, transparent basis for assessing shallow-water mooring solutions. Its focus is on strengthening the consistency and robustness of shallow-water mooring feasibility assessments, clarifying the verification routes for new permanent shallow-water mooring concepts, and establishing how to demonstrate that these concepts can achieve a reliability level comparable to conventional shallow water mooring systems.

Research Partners:
MARIN

1. BACKGROUND

Traditionally, permanent mooring systems in deep water, and temporary mooring systems in shallow water have evolved under very different engineering philosophies because they serve fundamentally different roles in the marine environment. These differences include: **(1)** the *purpose* of the mooring, which ranges from long-term station-keeping of offshore production units to operational berthing in shallow water terminals; **(2)** the *environmental conditions* considered in design, with offshore systems built for extreme open-ocean storms on one hand, and often nearshore systems driven by local wind, tide, infragravity waves, and port-specific constraints on the other hand; **(3)** the *primary design drivers*, such as extreme-event survival and fatigue for permanently moored systems in deep water offshore versus operational safety and cargo-handling continuity for temporary moored systems in shallow water; **(4)** the *mechanical components* involved, from seabed-anchored catenary or taut-leg systems for permanently moored systems offshore to bollards, hooks, and fenders integrated into infrastructure for the temporary mooring in shallow water; **(5)** the role of *shallow-water effects*, which are central to design of shallow water mooring systems but only occasionally relevant offshore; **(6)** the *risk focus*, shifting from high-consequence failures affecting subsea assets for permanently moored systems offshore to line-handling safety and infrastructure protection in temporary moored systems in shallow water; **(7)** the *duration* of mooring, typically multi-year or permanent offshore versus operational or semi-permanent for the temporary mooring in shallow water; and **(8)** the *regulatory ecosystems*, where deep water offshore systems follow classification-society mooring standards while temporary shallow water systems increasingly fall under IMO's enhanced mooring-equipment and line-management requirements or operational guidelines as OCIMF, SIGTOO and PIANC. Together, these distinctions create two parallel but interconnected design cultures that reflect the very different worlds in which permanently moored systems in offshore deep water, and temporary moored systems in shallow water operate.

As industry needs evolve, the historically separate design cultures of permanent mooring in deep water, and the temporary in shallow water are beginning to overlap. This shift is driven by the growing number of shallow water facilities that are no longer moored for only a few days at a time, but instead remain in place for many years. These systems occupy a hybrid space: they are geographically in shallow water, yet functionally *permanently moored*. Examples include LNG import and export terminals, floating energy-storage units, and other facilities positioned close to onshore power plants or producing assets.

Designing such long-duration moorings in shallow water introduces a unique set of challenges. Limited footprint and anchor depth, high line tensions, anchor uplift, large tidal variations, and greater uncertainty in environmental loading can all drive the system toward more complex, costly, and highly engineered solutions - often approaching the rigor traditionally associated with offshore mooring design.

In that industry evolution, a wide range of innovative solutions have been used or proposed for systems moored in shallow water, incorporating components such as dampers, vacuum connectors, magnets, piles, yokes, struts and specialized lines. Yet, many of these technologies were originally developed for temporary mooring applications, and their long-term reliability in permanent shallow-water facilities remains insufficiently validated. By addressing mooring challenges of permanently moored floating structures in shallow water environments, this project seeks to accelerate adaption of innovation to increase the safety and effectiveness of future shallow water facilities worldwide.

Figure 1: Permanent mooring solutions in shallow water pose a challenge due to lack of standardized guidelines.

Motivation

The SWIM JIP is motivated by the rapid growth of shallow-water facilities that demand long-duration mooring solutions far beyond the limits of traditional shallow water practice. As operators seek innovative, space-efficient, cost-effective systems, and safe systems (broken mooring ropes regularly cause severe injuries and fatalities in the maritime sector) a broad range of new technologies has emerged. However, many of these solutions were originally designed for short-term or operational mooring, leaving their long-term performance in permanent shallow-water environments insufficiently demonstrated.

This creates a critical gap: the industry needs innovation, but it also needs confidence in the reliability of these systems. The SWIM JIP aims to close this gap by addressing the unique technical challenges of permanent shallow-water mooring, comparing the various codes, rules and guidelines that govern such systems, mapping existing technologies and their applicability ranges, and reviewing methodologies for assessing the reliability of mooring components and the implications of potential failures. In doing so, the project establishes a shared and transparent basis for evaluating shallow-water mooring solutions by strengthening the consistency and robustness of feasibility assessments, clarifying verification routes for new concepts, and defining how to demonstrate that these concepts can achieve a reliability level comparable to conventional permanently moored systems in deep water — thereby supporting safe innovation and creating a level playing field for all technologies.

It is noted that the relevance of this work extends beyond the mooring industry itself and the oil and gas industry. The energy transition is driving the deployment of new shallow-water floating facilities associated with LNG, ammonia, hydrogen, CO_2, and other emerging energy carriers, as well as floating storage and conversion units that support the integration of renewable energy systems. Many of these facilities require safe, reliable, and cost-effective long-duration mooring solutions in locations where conventional offshore approaches may be impractical or uneconomic. By reducing uncertainty in the application of innovative mooring concepts, the SWIM JIP supports the development of critical infrastructure needed for a resilient and sustainable energy system, thereby contributing to the Dutch Knowledge and Innovation Agenda (KIA) objectives related to energy transition, climate, and maritime innovation.

Table 1: comparison of key aspects between permanent mooring in deep water, and temporary mooring in shallow water

Aspect	Permanent Mooring in Deep Water	Temporary Mooring in Shallow Water
Purpose	Long-term station-keeping for offshore units such as FPSOs, MODUs, floating wind platforms, and other deep-water assets.	Secure vessels or floating terminals at jetties, quays, or dolphins for cargo transfer, berthing, or semi-permanent nearshore operations.
Environment	Exposed to extreme open-ocean wind, wave, and current conditions; design typically based on 100-year or 10,000-year return periods depending on asset criticality.	Semi-sheltered or sheltered coastal environments with local wind, tide, and wave constraints; environmental limits must be specified and justified for the terminal location.
Primary Design Drivers	Extreme-event survival, fatigue life of mooring lines, redundancy (e.g., line failure criteria), and protection of subsea infrastructure.	Operational continuity at berth, safe cargo handling, mooring line integrity, and compliance with terminal-specific operational limits.
Typical Components	Seabed-anchored systems: catenary, taut-leg, or semi-taut moorings using chain, wire, or synthetics; suction piles or drag anchors.	Shore-integrated systems: bollards, quick-release hooks, fenders, breasting and mooring dolphins; short mooring lines to fixed structures.
Shallow-Water Considerations	Offshore systems are often deep-water, but shallow-water deployments require special analysis of line geometry, uplift, and anchor capacity.	Nearshore systems inherently operate in shallow water
Risk Focus	High-consequence failures: loss of station, riser damage, collision, environmental spills; requires extreme-event design and redundancy.	Operational safety: line failure during berthing, crew safety, equipment integrity, and protection of terminal infrastructure. New IMO rules emphasize safe mooring practices and line management.
Duration	Often permanent or multi-year mooring for production units or long drilling campaigns.	Short- to long-term depending on terminal type; some nearshore units (e.g., FSRUs, floating power plants) remain moored for their entire service life.
Regulatory Ecosystem	Governed primarily by offshore classification rules (e.g., DNV, ABS, LR) for positional mooring systems, including extreme-environment design criteria and anchor/line performance requirements. Offshore rules focus on seabed-anchored systems and long-term station-keeping.	Governed by IMO SOLAS amendments and associated circulars for safe mooring (MSC.1/Circ.1619 for design and equipment selection; MSC.1/Circ.1620 for inspection and maintenance). These rules strengthen requirements for mooring line strength, equipment selection, and maintenance practices. Nearshore long-term mooring systems at terminals are also subject to additional classification requirements specific to at-shore facilities. Operational Guidelines such as OCIMF, SIGTTO, PIANC.

2. OBJECTIVES

The SWIM JIP seeks to establish a shared, transparent basis for assessing shallow-water mooring solutions. Its focus is on strengthening the consistency and robustness of shallow-water permanent mooring feasibility assessments, clarifying the verification routes for new permanent mooring concepts in shallow water, and establishing how to demonstrate that these concepts can achieve a reliability level comparable to conventional permanent mooring systems in deep water. By doing so, the project aims to level the playing field for different technologies, support safe innovation, and enhance understanding of the specific risks and performance considerations associated with shallow-water environments.

3. SCOPE OF WORK

In order to achieve these objectives, the JIP will combine workshops with stakeholders, review of the regulations by classification societies, review of the existing mooring systems, and review of the standardized methodology on how to verify new mooring systems and how to demonstrate their equivalency to conventional mooring systems. A case study with one or more mooring systems will demonstrate how the methodology can be applied.

1

WP1 - WE ASSESS THE LANDSCAPE OF SHALLOW WATER MOORING SYSTEMS

We identify the key challenges of shallow-water mooring, review existing solutions and their performance, assess emerging technologies and their TRL, and examine current design practices and gaps for semi-permanent applications. We do this working together with operators, suppliers, class societies, researchers, and mooring specialists. The outcome is a consolidated overview of shallow-water challenges, available technologies, industry experience, and remaining gaps.

2

WP2 - WE COMPARE STATE OF THE PRACTICE

We map all relevant design codes for shallow-water mooring, identify the risks they do not fully address, define the additional design requirements needed to close those gaps, and outline suitable verification methods. The deliverable is a clear, consolidated set of codes, gaps, and recommended requirements for shallow-water mooring design.

3

WP3 - WE ASSESS EXISTING MOORING SOLUTIONS

We review existing mooring systems and proposed technologies, map which shallow-water challenges each solution addresses and the conditions where it is effective, and assess their track record in both short- and long-term use. The deliverable is a clear overview of existing systems and their applicability range.

4

WP4 - WE IDENTIFY RELIABILITY ASSESSMENT METHODS

We identify suitable reliability methods for active mooring components such as winches, dampers, and tensioners, and ensure balanced system-level reliability by aligning expectations between static and dynamic elements. The deliverable is a clear description of how to evaluate the reliability of each mooring component and the consequences and criticality of potential failures.

5

WP5 - APPLICATION TO A CASE STUDY - SYSTEM 1

We test and demonstrate the completeness and applicability of the verification pathway as defined in WP2 and reliability methodology as defined in WP4, for a specific type of mooring system selected among the mooring systems discussed in with the participants in WP3.

Figure 2: summary of the Work Packages

The total scope of work of the proposed JIP has been separated into the following main work packages:

WP1: Landscape Assessment of Shallow Water Mooring Systems (Lead MARIN)

Purpose: The purpose of the landscape assessment is to establish a comprehensive, shared understanding of the shallow-water mooring domain by mapping the key challenges, reviewing existing and proposed technologies, assessing their applicability and maturity, and identifying gaps in current design practices. This provides the baseline knowledge needed to guide all subsequent work in the SWIM JIP.

Scope:
- Co-creation workshop: collaboration with operators, suppliers, class societies, researchers, and mooring experts in which the following aspects are discussed:
  - Technologies: review existing and upcoming mooring systems and technologies potentially applied in the energy sector for permanently mooring systems in shallow water. Assess the track record of each system for both short-term and long-term mooring applications (data driven), then identify and document in this assessment the industry experience with shallow-water mooring (based on experience from participants).
  - Challenges: define and categorize the key challenges associated with permanently mooring assets in shallow water, addressing both design and operational aspects, as well as the challenges arising from the variety of applicable verification guidelines.
  - Mapping: which shallow-water challenges each technology addresses and the parameter ranges where it is effective, which technology has been assessed according to which guidelines or rules.

Deliverable:
- One (1) report or infographics that summarizes the outcome of the workshop

WP2: Comparison of Codes[1], Rules[2] and Guidelines[3] (Lead TBC)

Purpose: The purpose of this work package is to compare all relevant design codes for shallow-water mooring as identified in the landscape assessment. Also, we will identify where current rules fall short for innovative or active components, and define the additional requirements and verification methods needed to ensure safe, consistent, and reliable design of permanent shallow-water mooring systems.

Scope:
- Present overview of verification methods (codes, rules and guidelines) for design of shallow water mooring systems
- List risks/gaps that are not addressed by design codes/rules/guidelines
- List differences/discrepancies between the design codes/rules/guidelines
- List methods that can be used to address these gaps

Deliverable:
- One (1) report or infographics that summarizes the outcome of the comparison study

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[1] Codes are high-level, often legally recognized standards issued by international bodies (e.g., IMO), national authorities, or classification societies. They define the minimum safety, environmental, and performance requirements that must be met.
[2] Rules are detailed, prescriptive technical requirements issued mainly by classification societies (DNV, ABS, LR, BV, etc.). They specify how to design, analyse, and verify a system so that it complies with the overarching codes.
[3] Guidelines are non-mandatory, advisory documents that provide recommended practices, interpretations, or methodologies. They help engineers apply codes and rules in a consistent, practical, and technically sound way

Table 2: comparison between codes, rules and guidelines

Aspect	Codes	Rules	Guidelines
Authority	International/national regulators (IMO, ISO)	Classification societies (DNV, ABS, LR, BV)	Industry bodies, class societies, operators
Mandatory	Often yes	Yes for classed units	No (unless contractually required)
Detail level	High-level	Very detailed	Medium, explanatory
Purpose	Define minimum safety requirements	Provide prescriptive design criteria	Offer recommended practices and interpretations
Flexibility	Low	Medium	High
Examples for moored vessels & offshore units nearshore	IMO MODU Code	LR Offshore Rules, DNV-RP-E301 (Mooring Design and Installation), BV NR493 (Mooring Systems for Offshore Units), ABS Rules for Building and Classing Offshore Units (2025)	DNV-OTG18, OCIMF MEG4, PIANC Guidelines for moored ships in ports,

WP3: Review of existing mooring solutions (Lead MARIN)

Purpose: The purpose of the review of existing mooring solutions is to build a clear, evidence-based understanding of what mooring systems and technologies are already available for shallow-water mooring. It creates the technical foundation for deciding what systems are interesting to dig into more details in work package 5 (case study). The list of mooring systems considered here is based on the landscape assessment done in WP1.

Scope:

- Review existing systems and proposed technologies to date
- List track record of each considered mooring system or upcoming technology for short-term and long-term mooring
- Map out which challenges associated with shallow water mooring they address
- Map out in which parameter range they are effective or have been used so far

Deliverables:

- One report

WP4: Reliability Assessment Methods (Lead TBC)

Purpose: To assess the reliability level of dynamic mooring components, engineers typically combine qualitative, quantitative and data-driven methodologies. Each method captures a different aspect of how components behave under dynamic loading. Each method provides a different lens, and in practice, multiple methods are combined to achieve a robust reliability assessment. Dynamic mooring component reliability is assessed using a combination of the methods listed in the table below.

Table 3: list of reliability assessment methods

Methodology	Type	Focus	Typical Use
Bow-Tie	Qualitative	Causes, consequences, barriers	Operational risk, barrier management
FMEA/FMECA	Qualitative	Component failure modes	Design review, maintenance planning
HAZID/HAZOP	Qualitative	System hazards	Early design, operations
Rule-based ULS/FLS/ALS	Deterministic	Safety factors, extreme loads, fatigue	Class compliance
FORM/SORM	Quantitative	Failure probability	Reliability-based design
Monte Carlo	Quantitative	Uncertainty propagation	Long-term reliability
Fatigue reliability	Quantitative	Fatigue life, degradation	Chains, connectors, shallow water
Fault-tree/Event-tree	Quantitative	System-level reliability	Line-loss scenarios
RBDO	Quantitative	Optimization under uncertainty	Cost-risk optimization
SHM	Data-driven	Real-time loads & degradation	Integrity management
Digital twin	Data-driven	Predictive reliability	High-value assets
Bayesian updating	Data-driven	Updating reliability with data	Long-term mooring
Inspection-based	Data-driven	Actual condition	Life extension

The purpose of this work package is to establish consistent, fit-for-purpose reliability methodologies for innovative mooring components, or the path towards this. This ensures that innovative component reliability can be aligned with that of conventional mooring elements. By analysing broad classes of innovative systems through structured bowtie workshops, the work package builds a shared risk register and provides the foundation for balanced, system-level reliability assessment across all mooring technologies.

Scope:

- Expert presentations explaining the different types of reliability assessment methods
- Workshop with bowtie analysis on broad classes of systems (dampers, struts, vacuum connectors, etc) to establish a risk register example.

Deliverables:

- A workflow showing how the different reliability methods fit into a mooring integrity workflow, from design, to verification, to operation, to life extension.

WP5: Case Study (Lead MARIN)

Purpose: the purpose of the case-study work package is to test and demonstrate the completeness and applicability of the design methodology as defined in WP2 and reliability methodology as defined in WP4, for a specific type of mooring system discussed with the participants in WP3.

The WP5 builds up on the generic lessons learned from the previous work packages and can be repeated as more mooring systems will be investigated within the JIP. For example, a standard jetty mooring system could be investigated as a first case (WP5.1), being followed by other mooring system such as a submerged soft-yoke (WP5.2), a system with active damper (WP5.3)…

Scope:

- Selection of the mooring system to be investigated (WP3)
- Selection of the environments
- Build numerical model for the shallow water system in a selected multiyear environment

- Discuss the reliability analysis workflow with
  - Bowtie workshop for the investigated mooring system
  - Long term analysis by multiyear time-domain computations (aNySIM)
- Evaluate simulations for different fidelity levels of the numerical modelling, to demonstrate the effects of the modelling assumptions made on the reliability assessment

Deliverables:
- Report and data (time traces and statistics) of the mooring simulations

4. PROJECT DELIVERABLES

Below an overview is given of the SWIM deliverables:

- Overview of available technologies, experience and challenges (WP1)
- Overview of codes, gaps and recommendations (WP2)
- Overview of permanent mooring solutions for shallow-water applications and their applicability range (WP3)
- Description of methodologies to assess active components reliability (WP4)
- Practical case study example (WP5) in which one or more mooring system is looked in more depth

5. ORGANISATION AND SCHEDULE

The SWIM JIP will kick-off in 2026 and will be conducted as a 1.0 year Joint Industry Project in close co-operation with energy companies, mooring design companies and classification societies. MARIN will act as JIP manager and sign participation agreements with all members. All participating companies will be represented in the JIP Steering Group with meetings every 6 months within the FPSO JIP week. Presentations, reports and other relevant info will be posted on the confidential project website.

6. BUDGET AND PARTICIPATION FEES

For the SWIM JIP, we aim for a total project scope of 160kEuro for the base scope of work. The present proposal is based on that assumed minimal total budget. To reach that total budget we propose a participation fee of 40 k€ for the participants. Based on this budget, one type of mooring system can be investigated in the case study.

Participants can join the JIP until December 1st, 2026. After that a late participation fee of 125% applies. The final budgets and scope of work will be fixed in accordance with the JIP participants during the kick-off meeting.

Table of Expenditures for the Minimum Scope of Work

Activity	Work Package	Budget	2026		2027				2028			
			Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP1	Landscape assessment	€ 20.000										
WP2	Comparison of codes, rules and guidelines	€ 20.000										
WP3	Review of existing mooring solutions	€ 30.000										
WP4	Map out reliability assessment methods	€ 20.000										
WP5	Case Study - Mooring System 1	€ 50.000										
WP5	Case Study - Mooring System 2 (optional)											
WP5	Case Study - Mooring System 3 (optional) ..etc											
	Project Management	€ 20.000										
	Total	€ 160.000										

7. CONTACT

For more information please contact MARIN:

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APPENDIX : RESPONSE FORM / LETTER OF INTENT FOR SWIM JIP

Please e-mail to : MARIN, Frédérick Jaouën

Project reference XXXXX

f.jaouen@marin.nl
Tel: +31-317 493 509 (direct)

Company/organization : ....

Contact person : ....

E-mail address : ....

Signature : ....

Please tick:

O We intend to become a SWIM participant.
However, we have the following comments to proposed scope of work:

O We do not have interest in this JIP, please remove us from the contact list.