SMaRC
SWEDISH
MARITIME
ROBOTICS
CENTRE

Annual Report 2025

Swedish
Maritime
Robotics
Centre

INTRODUCTION

The Swedish Maritime Robotic Centre (SMaRC) was formally established in late June 2024, following the signing of a landmark agreement between key national players. Backed by the Swedish Defence Materiel Administration (FMV), SAAB, and KTH Royal Institute of Technology, the Centre brings together cutting-edge expertise and funding to position Sweden at the forefront of underwater innovation.

SMaRC is set to drive progress through a range of core activities:

- Conduct world-class research in underwater robotics
- Serve as a national hub for advanced underwater technology
- Operate the Maritime Research Laboratory, a central and fully integrated part of the Centre
- Engage and inform the wider community about its ongoing work and developments

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2025 ACTIVITIES

The inauguration of the SMARC ecosystem
The SMaRC ecosystem continued to expand during 2025. A key driver of this growth has been the initiative and ambition of the involved researchers to broaden and deepen their research activities. It is important to note, however, that this development was made possible by the existing SMaRC assets, which provide the foundation for sustained progress.

In particular, the Centre supports the operation, development, and maintenance of advanced robotic platforms, establishing shared infrastructure that allows researchers to undertake ambitious projects and foster international collaborations.

This infrastructure has proven to be a vital enabler for participation in large international programmes.

For example, participation in several European Defence Fund (EDF) projects has only been possible because SMaRC could provide its robotic systems as in-kind contributions. The availability of these operational platforms has therefore been a crucial factor in enabling Swedish researchers to participate in major European research and innovation initiatives.

The financing scenario is shown in Figure 1, which displays the ecosystem from a defence viewpoint. Figure 1 illustrates the complete defence-related ecosystem at KTH, with an annual turnover of around 24 million SEK at the end of 2025.

This demonstrates a significant leverage effect for the Swedish Navy and SAAB, equivalent to an upscaling factor of about six, with an investment of roughly 4 million SEK generating activities worth 24 million SEK. When civilian projects and collaborations are also included, the overall leverage and impact of the ecosystem become even greater, highlighting the broader value of the SMaRC platform in supporting both security and dual-use innovation.

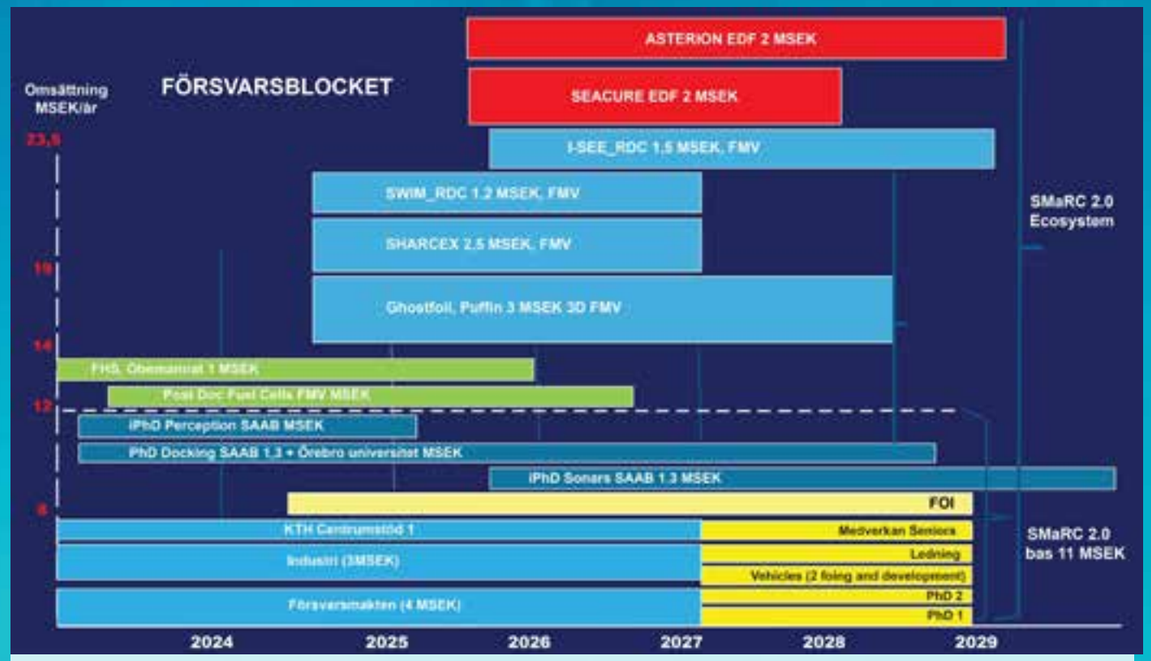

Figure 1: Defence related projects running at KTH. The lower blue bars show the contribution from the founders of SMaRC; FMV (FM), SAAB, and KTH. The red blocks are European Defence Foundations (EDF) funded projects.

SMARC - Network catalysts

The role of SMaRC is not only to serve as the national hub for maritime robotics, but also to act as a catalyst for collaboration, networking, and innovation across Sweden's maritime sector. By bringing together researchers, industry partners, government agencies, and international stakeholders, SMaRC creates a platform where ideas, technologies, and expertise can meet and develop.

Through workshops, joint exercises, research collaborations, and strategic partnerships, SMaRC actively stimulates new connections and initiatives that strengthen the national capability in maritime robotics and autonomous systems. These networking activities enable knowledge exchange, foster interdisciplinary cooperation, and help translate research results into practical applications.

In this way, SMaRC functions not only as a research centre but also as a coordinating node that connects academia, industry, and public actors, supporting both technological advancement and the growth of a strong national maritime robotics ecosystem.

Networking events arranged during 2025:
Underwater Technology Days at KTH
SMaRC organised a one-day conference to strengthen networking and showcase ongoing projects in the field. The UTD is the only one of its kind in Sweden for Swedish actors. The conference was hosted at KTH, attracting more than 60 participants from across the sector.

The event was highly appreciated, both for the insightful presentations on current research and development activities and for the valuable opportunities for networking and exchange. Participants represented a broad spectrum of stakeholders, including industry, government agencies, the Swedish Armed Forces, and small and medium-sized enterprises (SMEs). The conference contributed to strengthening connections within the national maritime robotics ecosystem and highlighted the growing interest in collaboration across research, defence, and industry.

Conference participants at the first Underwater Technology Days at KTH.

Demonstration Day

Since its inception, SMaRC has organised an annual Demonstration Day at the Marine Research Station on Askö. This event provides an opportunity for ongoing projects to showcase the new capabilities and technologies developed over the year. It serves a dual purpose: firstly, to give Swedish stakeholders, including industry, government agencies, and defence actors, a hands-on opprtunity to see how research concepts and theoretical developments are translated into operational capabilities using SMaRC's robotic platforms on and below the sea surface; secondly, to act as a test and validation arena for SMaRC researchers to deploy and evaluate their algorithms, systems, and innovations in realistic maritime environments. This opportunity to test solutions at sea is a vital part of accelerating the transition from research to operational capability.

Collectively, these activities strengthen collaboration across the Swedish maritime robotics community while demonstrating the practical impact of SMaRC's research. The DEMO-day drew more than 60 invitees and received a positive response.

Participants arriving at Askö for the annual 2025 DEMO day.

BRINGING IN EXCELLENCE TO SMARC

Embodied Cognition – the route forward for autonomous robots

A crucial capability for autonomous robots is reflective cognition. It is the ability to reason about their actions and adapt their behaviour based on experience.
For underwater robotic systems, this capability must be embodied, meaning that reasoning, perception, and learning must be performed on board the vehicle itself, due to the limited communication bandwidth available underwater. The scientific field addressing these challenges is known as Embodied Cognition, which studies how intelligent behaviour emerges from the interaction between a robot's physical body, its sensors, and its environment. In Sweden, Örebro University (ÖU) is a leading actor in this field, with a research group dedicated to embodied cognition and autonomous systems. Recognising the strategic importance of this expertise, SMaRC has identified strong potential benefits in engaging ÖU more closely within the SMaRC ecosystem, thereby strengthening Sweden's overall capabilities in advanced robotics and autonomous maritime systems. As a result, discussions have been initiated to establish a collaboration between Örebro University and SMaRC. To support this initiative, funding has been allocated for the period 2026–2027, enabling researchers at ÖU to address key research questions related to maritime robotics within the SMaRC framework. This collaboration is expected to strengthen the integration of embodied cognition and advanced autonomy into maritime robotic systems, further enhancing Sweden's capabilities in intelligent autonomous platforms.

LSTS - The World Leading Actor on Underwater Robots and Swarming

The Laboratório de Sistemas e Tecnologia Subaquática (LSTS) is an interdisciplinary research laboratory founded in 1997, bringing together researchers in Electrical and Computer Engineering, Mechanical Engineering, and Computer Science. The laboratory specialises in the design, development, and operation of unmanned underwater, surface, and aerial vehicles, as well as technologies for coordinated and networked vehicle systems. Since 2025, LSTS has been a partner in SMaRC, contributing through co-supervision of PhD students and collaboration on joint research proposals.

DEMONSTRATION OF NOVEL ROBOTIC CAPABILITIES

SMaRC Working Horse - The Long Range and Long Endurance Robot (LoLo)

In 2024, the LoLo underwater robot underwent a significant upgrade to enable Arctic exploration and deep-sea operations. The platform was prepared for dives down to 1000 meters depth, substantially expanding its operational envelope.

As part of the upgrade, the battery system was replaced and expanded, allowing for longer mission durations and extended measurement campaigns. LoLo was also equipped with a suite of advanced sensors, including a Norbit Long-Range Multibeam sonar and a scientific echosounder (EK80) from Kongsberg, enhancing its capability for high-resolution mapping and scientific observation. LoLo has proven to be a highly versatile and reliable research platform, enabling rapid development, testing, and deployment of new technologies and algorithms. Following the upgrade, the system has been used in several field trials and operational experiments, some of which are described below.

The SMaRC flagship LoLo submerged on a mission.

How do you dock two moving platforms underwater when GPS is unavailable? By listening!

In summer 2025, our autonomous underwater vehicle LoLo proved that this vision is becoming reality. During sea trials at the Askö research station in the Stockholm Archipelago, LoLo successfully tracked and approached a moving vessel on its own, demonstrating a new level of autonomy in underwater operations. The vehicle could locate its target, follow it, and move into close proximity, laying the groundwork for dynamic underwater docking. This capability opens the door to a new generation of coordinated marine robotics. Autonomous vehicles could soon rendezvous underwater to exchange data, transfer payloads, or collaborate on complex missions without needing to surface. What once required large ships and human divers may soon be handled by intelligent underwater robots working together beneath the waves. LoLo shows that the future of autonomous underwater collaboration is already taking shape.

What if underwater robots could talk to each other, instantly and without surfacing?

In September 2025, the AUV LoLo took another step toward fully autonomous collaboration beneath the sea. Equipped with a new optical communication system, LoLo successfully exchanged information with another platform during sea trials. The tests showed that underwater vehicles can send data directly to one another while on mission, opening the door to real-time coordination, smarter teamwork, and faster decision-making below the surface. Imagine fleets of underwater robots sharing maps, mission updates, and discoveries as they explore the ocean together. The prerequisite for this demonstration was LoLo.

What if autonomous boats didn’t just sail the ocean… but flew over it?

The Evolo, an unmanned hydrofoiling research platform designed to explore the future of maritime robotics. By lifting its hull above the water on sleek hydrofoils, Evolo dramatically reduces drag, allowing it to move faster, more efficiently, and more stealthily than traditional small vessels.

But Evolo is more than a spearheading platform. It is a floating laboratory for the next generation of intelligent marine systems. Packed with advanced sensors and real-time control, the platform explores how autonomous vessels can safely navigate complex ocean environments while sharing the sea with other ships. Its modular design allows researchers to rapidly test new sensors, autonomy concepts, and cooperative mission capabilities, helping shape the future of distributed maritime robotics. In 2025, Evolo proved its potential during the international REPMUS exercise, successfully demonstrating advanced capabilities (full C2 operability with STAGNAG 4817 implemented) in a demanding operational environment.

Evolo shows how tomorrow’s autonomous marine vehicles may move faster, smarter, and more efficiently across the oceans.

Two Puffins on the dock. Cheap, affordable and even expandable.

Puffins - Small Robots, Big Missions
What if a mission could be carried out by armadas of tiny and expandable robots?
Meet the Puffins a low-cost micro-AUVs designed to work together as intelligent underwater teams. Small, agile, and affordable, Puffins are powerful tools for both cutting-edge research and hands-on education for PhD, MSc, and BSc students.

On the surface, Puffins can move in coordinated formations. When it's time to explore, they simply reverse their twin propellers and glide down toward the seafloor. Once there, a clever passive buoyancy system allows them to rest on the seabed for long periods, quietly collecting valuable ocean data.

Even more exciting developments are underway: enabling Puffins to communicate with each other and with other underwater systems, listen to the ocean using hydrophones, and eventually reposition themselves on the seabed. These capabilities turn Puffins into a powerful platform for experimenting with swarming marine robots and distributed ocean sensing. Already proven in real-world operations during REPMUS 2025, Puffins show how fleets of small robots can transform the way we explore and protect our seas.

How can naval underwater robots remain on mission longer without returning to base?
Hydrogen fuel cells might provide the solution. This technology transforms the chemical energy in hydrogen into electricity, generating only heat and water as byproducts. For underwater robots, fuel cells can be combined with batteries to deliver both high power and extensive energy capacity. Hydrogen also offers several benefits over traditional battery systems. It allows for rapid refuelling, supports larger energy storage, and has a significantly higher energy density. Consequently, underwater vehicles could undertake much longer missions without surfacing. However, fuel cells designed for cars or stationary power units are not immediately suitable for underwater robots. Subsea vehicles are often constrained by volume rather than weight, opening opportunities for new system designs. They also need a supply of oxygen for the electrochemical process, which allows for closed system solutions. Researchers are even investigating concepts where the surrounding seawater could contribute to the process. For SMaRC researchers, this technology could represent a crucial step towards longer-range, more capable, and more sustainable underwater robotic missions.

The KTH fuel cell system was compactified and ready to go for its first underwater mission.

Visits from the Swedish Ministry of Defence
The Swedish Ministry of Defence visited SMaRC alongside a large Polish delegation, emphasising the Centre's growing significance as a national capability in maritime robotics. SMaRC acted as a focal point during the visit, and a presentation was given on how the Centre supports the Swedish Armed Forces' strategic investments in low-TRL technologies and early-stage innovation. The visit took place shortly before Poland announced its decision to procure Swedish submarines, underscoring the broader strategic relevance of Swedish maritime research and technological expertise.

The Singapore Ministry of Defence (MINDEF) visited SMaRC in 2025 as part of the bilateral Memorandum of Understanding (MoU) on defence innovation between Singapore and Sweden, which encourages regular exchanges on emerging technologies and collaborative research.This proposed collaboration seeks to strengthen long-term cooperation in robotics, autonomy, and maritime technologies of strategicimportance. The proposal is currently under review by the Swedish Defence Materiel Administration (FMV).

SMaRC at REPMUS – A Demonstration of Operational Excellence
SMaRC participated in the REPMUS exercise, where its contribution was highlighted by FMV as a success story. Only a few teams demonstrated full Command and Control (C2) capability with STANAG 4817 integration, placing SMaRC among a select group operating at the highest level of interoperability. During the exercise, KTH launched the foiling platform Evolo carrying two autonomous underwater drones (Puffins). From a home base operated by the Swedish Navy, Evolo executed a fully autonomous mission. The platform took off, navigated to the designated operational area, and deployed the two drones precisely at the specified location. Once in the water, the drones coordinated their positioning and dived to search for an underwater communication cable. The target was successfully located, demonstrating a complete end-to-end autonomous mission capability. This operation showcased how advanced maritime autonomy, robust C2 integration, and innovative platforms can work together to deliver reliable, mission-ready solutions for complex underwater operations.

SMaRC in the EDF Project ASTERION – Advancing Directive Underwater Communication
SMaRC participates in the European Defence Fund (EDF) project ASTERION, a major European initiative developing next-generation underwater communication systems for autonomous maritime operations. The project is coordinated by TNO and brings together 19 organisations across Europe to create a secure and interoperable communication architecture for underwater systems.

ASTERION focuses on developing a flexible and universal communication architecture that connects underwater vehicles, sensors and command nodes. The architecture supports different data rates and waveforms and aims to establish standardised protocols for future underwater networks. Within ASTERION, SMaRC contributes research on directive underwater communication and associated communication protocols, enabling underwater vehicles to communicate more efficiently and securely (covert). Directive communication techniques focus acoustic energy toward the intended receiver, improving signal-to-noise ratio, increasing range and reducing the risk of interception in complex underwater environments.

SMaRC’s contribution demonstrates how advanced signal processing, directive communication methods and standardised protocols can enable reliable underwater networking for future autonomous maritime operations.

SMaRC in the EDF Project SEACURE – Protecting Critical Seabed Infrastructure
SMaRC participates in the European Defence Fund project SEACURE, a major European initiative to develop autonomous capabilities for anti-submarine and seabed warfare. The project brings together 35 partners from 13 European countries and aims to demonstrate an integrated system-of-systems using aerial, surface and underwater drones to protect critical maritime infrastructure.

The objective of SEACURE is to develop and demonstrate, by 2028, a coordinated autonomous capability able to detect, classify, identify and track underwater threats, while safeguarding infrastructure such as seabed communication cables, pipelines and offshore energy installations. Within SEACURE, SMaRC contributes expertise in seabed infrastructure monitoring using autonomous underwater vehicles.

A key capability being developed is the ability to inspect subsea cables and other critical assets to detect potential damage, tampering or manipulation. In a typical mission scenario, an autonomous underwater vehicle such as LoLo is deployed to follow a subsea cable along the seabed. The vehicle navigates precisely along the cable route while collecting high-resolution sensor data. Using onboard perception systems, the vehicle can detect anomalies such as disturbances, structural damage, or signs of external interference. The collected data is transmitted to command systems where the condition of the infrastructure can be assessed. This enables rapid detection of potential threats and supports the protection of critical underwater infrastructure that modern societies depend on, including communication networks and energy systems. Through its contribution to SEACURE, SMaRC demonstrates how autonomous robotics, advanced perception and coordinated unmanned systems can provide reliable monitoring and protection of Europe’s seabed infrastructure.

OpTech conference in Poland
Participation in OpTech Poland arranged by the Polish Naval Academy and SAAB. Two years in a row SMaRC has participated as presenter in the OpTech conference. The objective has been to show the maturity of different capabilities of autonomous underwater robots. The focus was on underwater navigation and reflective cognition.

In SMARC's underwater tank at KTH, the next generation of underwater vehicles is put to the test. The 9 × 5 × 3 meter tank features a motion-tracking system that captures detailed movement beneath the surface.

Inauguration of the Marinarium

Although not formally part of SMaRC, the new Marinarium test facility at KTH represents an important addition to Sweden's marine research and innovation infrastructure. The Marinarium provides a controlled environment where highly complex experiments with underwater systems, sensors and autonomous platforms can be performed and validated. By enabling repeatable testing under realistic conditions, the facility will accelerate the development, verification and demonstration of new maritime technologies. As a national research asset, the Marinarium strengthens Sweden's capability in marine robotics, and subsea sensing, supporting both academic research and collaboration with industry and government partners.

STUDENT ENGAGEMENT AND EDUCATION

SMaRC does not offer courses or formal education in underwater technology. However, the centre's activities have greatly increased student interest in maritime robotics and underwater technology, drawing more students to engage in SMaRC-related research.

A key driver of this progress has been the launch of the Amanuenses School, an initiative to attract talented and motivated students to the maritime robotics sector. Through this programme, about five students have been recruited and given specific development tasks, enabling them to gain early practical experience in underwater technology and research. Furthermore, in 2025, around 25 students completed their Master's theses on topics related to underwater technology, many of whom were involved in projects and activities within the SMaRC ecosystem. Collectively, these initiatives help strengthen the future skill base in maritime robotics and subsea technology, supporting the attraction and training of the next generation of researchers and engineers in the field.

Overall impact, the flow of students with modern skills in underwater technology is steadily increasing. This is particularly important for both industry and the Swedish Defence Materiel Administration (FMV), which has a growing demand for highly qualified personnel in this field. The increasing number of students gaining experience in maritime robotics, autonomous systems and subsea technologies contributes to strengthening the national competence base needed to support future developments in underwater capability.

QUALITY ASSESSMENT & CONTROL

Peer-reviewed publications

A key question for the Centre is whether our work is both relevant and useful. Usefulness can be assessed in several ways. During the year, discussions were held with both SAAB and FMV to evaluate the relevance of SMaRC's research and its alignment with national needs. Their perspectives are important for the Centre, and we continuously adjust our research agenda to ensure that we address the most relevant technological challenges. At the same time, it is important to recognise SMaRC's role in the innovation chain. The Centre primarily focuses on low Technology Readiness Levels (TRL), exploring new concepts, methods, and technologies and advancing them towards higher levels of maturity. When combined with a well-functioning innovation ladder, this process can significantly shorten the path from research results to the introduction of new capabilities in operational systems used by the Armed Forces.

Another important indicator of whether we are pursuing the right research directions is scientific output. In 2025, approximately 14 peer-reviewed papers from SMaRC researchers were accepted and published. This demonstrates that the Centre continues to produce research of high scientific and engineering quality while addressing problems of practical relevance.

The External Scientific Advisory Board
The SMaRC project has a dedicated External Scientific Advisory Board that evaluates the research quality of the centre annually. The External Scientific Advisory Board (ESAB) serves to provide independent, high-level scientific and technical advice to the SMaRC management and research teams. Its primary role is to ensure the scientific excellence and relevance of the SMaRC projects by:

- Reviewing and guiding the scientific and technical progress of the projects.
- Advising on emerging scientific and technological developments relevant to the project.
- Offering strategic input on research direction, methodology, and innovations.
- Recommending opportunities for collaboration, dissemination, and policy engagement.

The ESAB members are:

Research Director Björn Ekelund, Ericsson
Vice Rektor Martin Jakobsson, Stockholms Universitet
Professor Nina Kirchner, Stockholms Universitet
Professor Amy Loutfi, Örebro University
Professor Martin Ludvigsen, Norwegian University of Science and Technology