NRIA-U 2016

National Innovation Agenda
for Underwater Technology

EDITORIAL INFORMATION
Text: NRIA-U 2016 is an agenda for Swedish underwater technology innovation outlining a national strategy up to 2030. The objective is to strengthen the preconditions for national competitiveness within the underwater technology sector. The document was compiled by academia, business and authorities (see participating organisations on page 30), all of which jointly own all the rights to this document. Reproduction of the content is permitted without authorization of the copyright holder subject to the source being clearly identified.
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DEFINITIONS OF TERMINOLOGY AND ABBREVIATIONS

NRIA-U ..... National innovation Agenda (National Research-and-Innovation Agenda, NRIA) for Underwater technology (U). See page 6 re: 'R'.

Innovation ..... The process that takes ideas to proven products on the market. (Note that "the market" in this context does not necessarily mean end-use; it may also encompass, for example, integration of a specific technology within an exisiting overall system.)

Innovation chain ..... Development of a specific technology from idea to proven product on the market. (Note the significance of "the market" in the definition of "innovation" above.)

TRL ..... Technology Readiness Level, a nine-level scale used to assess the maturity of an innovation. The scale starts at a basic research level (TRL 1) and ends at a proven product, available on the market (TRL 9). The scale complies with the definition of innovation and can therefore be used as an indicator of the maturity of an innovation. (Note the significance of "the market" in the definition of "innovation" above.)

Innovation area ..... Domain within business or professional activities where the innovational development of common technology is central. The innovation area for NRIA-U is underwater technology. The term can be assimilated to field of technology and can include a variety of different innovation chains.

Innovation system ... The number of functions required for innovation to be realised on a market. Consists of actors of internal and external character as described below and can include different innovation chains.

Internal actors ..... Actors active inside the innovation sector, for example academia, institutes and business.

External actors ..... Actors active outside the innovation sector but which are of critical significance for the innovation process, for example politicians, authorities, financiers and consultants as well as endusers of the invented products and services.

Dual use ..... A common technology that finds use in both civil and security & defence applications. The branching point should take place as late as possible to attain the greatest possible synergies and effectiveness of the innovation.

Multi use ..... As dual use but with the branching into multiple areas of application, for example, automotive and construction industries and the like.

Tecnology ..... The applied use of scientific knowledge.

IPR ..... Intellectual Property Rights, intangible rights.

ROV ..... Remotely Operated Vehicle, unmanned underwater vehicle that is remotely controlled by a human operator.

AUV ..... Autonomous Underwater Vehicle, unmanned underwater vehicle that can carry out its operations totally or partially independent of a human operator.

Batymetri ..... Underwater topography.

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About this document

The first national innovation agenda for underwater technology in Sweden – the document you are now reading – is a collaborative strategy made by actors within the field of underwater innovation that maps the way ahead.

WHY NRIA-U?

The underwater domain not only offers benefits in terms of resource extraction, security, infrastructure and environmental observations, but also employment, export revenue and recreation. In many respects, however, the underwater domain is uncharted territory. It is said that "we know more about the surface of the moon than we know about our oceans". Mankind has a tendency to prioritize the exploration of distant horizons over that of its immediate neighbourhood. The ocean is close to most people, not least in these times of global environmental challenges where the ocean plays a central role. By ocean we mean the *underwater domain* in its whole, that is, the volume between the ocean surface and the seabed.

For the future, we need to take strategic measures in order to manage, defend, research and exploit the ocean's potential in the best possible way. A significant number of these strategic measures are related to underwater technology innovation.

Sweden has, in relation to the size of its population, a unique competence in development of underwater systems. This has its cause in security & defence needs although over time a civil market has evolved – partly

as a result of the dissemination of defence technology and partly because the security & defence sector can no longer act isolated, but to a large extent has to coexist with civil innovation in a dual use relationship.

The Baltic Sea is a semi-enclosed sea characterized by intricate archipelagos, high volumes of ship traffic, sensitive biotopes, brackish water and special hydrographic conditions. This complex maritime environment has made Sweden particularly well qualified to work with underwater technology innovation. In Sweden, there is a long experience of technology and operations adapted to this unique environment in the form of offshore installations, anti-submarine warfare, mine counter measures, assessment of the environmental status of waters, as well as oxygenation and eutrophication.

However, in order to exist in the globalized world, innovation must be effective and efficient. Most of our innovation activities are conducted in and exposed to an internationally competitive market and the trend indicates that in the future even higher demands will be foreseen. Furthermore, innovation will be conducted in collaboration between different actors to an ever-increasing extent.

PURPOSE AND TARGET AUDIENCE

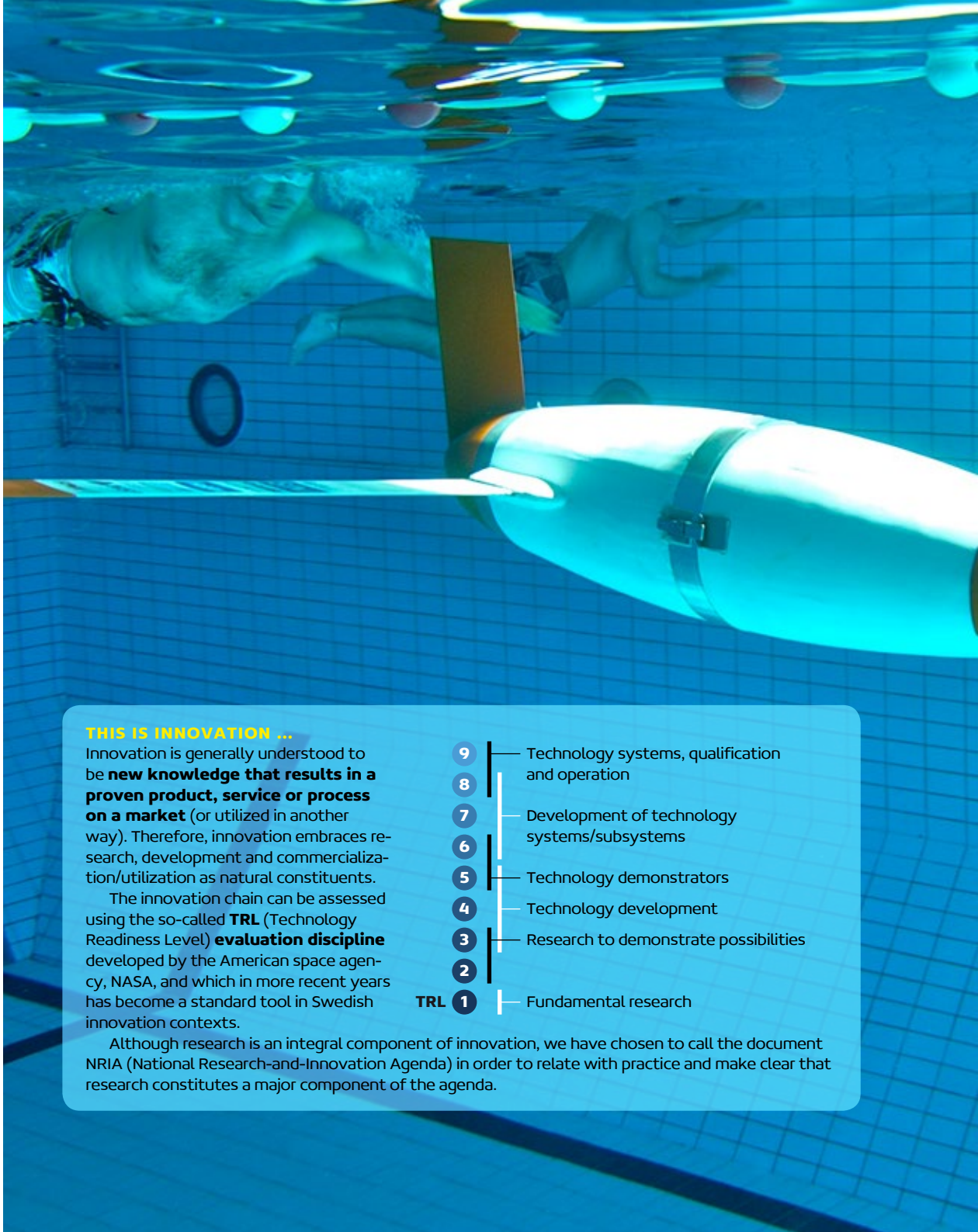
With the research and innovation agenda, NRIA-U, we aim to promote the potential of the Swedish underwater technology innovation area, with the main purpose of establishing Sweden's position and developing its international competitiveness.

The agenda transcends any vested interests within the national underwater technology area, focusing fully on the common interests, to achieve the desired competitiveness. The agenda's proposals set out to create the *preconditions* for innovation, which benefits all actors regardless of vested interests.

More specifically, NRIA-U aims to:

- raise the public attention of the significance of the Swedish underwater technology sector for society and increase its interest;
- widen and strengthen national networks within the sector;
- provide a basis for dialogues with financiers such as, business enterprises, Vinnova, SSF, Swedish Research Council and others;
- stimulate the relevant authorities to clarify their strategies and priorities;
- demonstrate the potential of the sector to contribute to benefits for Sweden within resource extraction, security, infrastructure and environmental management, with positive effects for Swedish international competitiveness as well as creating national job opportunities;
- quantify the needs to be achieved in order to boost the progress of Swedish underwater innovation and create opportunities for even better competitiveness for actors in Sweden.

NRIA-U is intended to serve as a unifying policy document for the actors of the underwater technology sector. The agenda also has the purpose of conveying a jointly formulated vision and present an action plan of how to reach the goals for politicians, authorities and financiers.

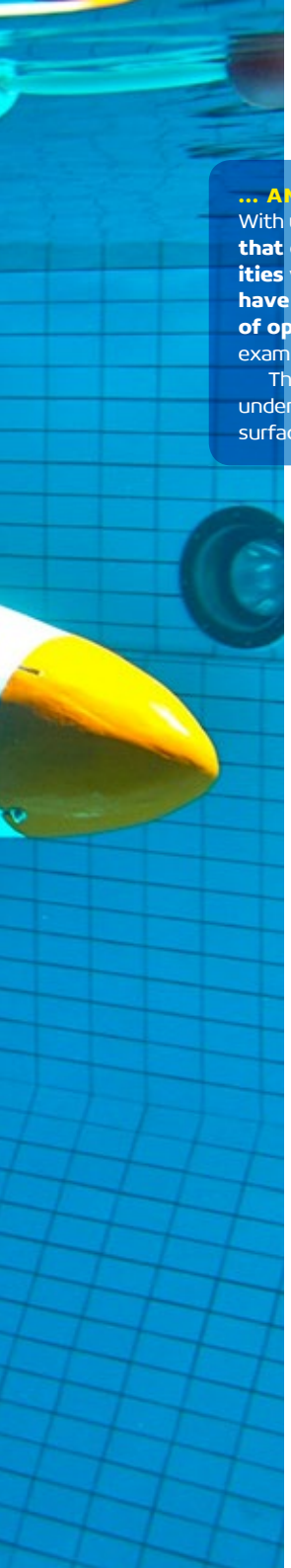


THIS IS INNOVATION ...

Innovation is generally understood to be **new knowledge that results in a proven product, service or process on a market** (or utilized in another way). Therefore, innovation embraces research, development and commercialization/utilization as natural constituents.

The innovation chain can be assessed using the so-called **TRL** (Technology Readiness Level) **evaluation discipline** developed by the American space agency, NASA, and which in more recent years has become a standard tool in Swedish innovation contexts.

Although research is an integral component of innovation, we have chosen to call the document NRIA (National Research-and-Innovation Agenda) in order to relate with practice and make clear that research constitutes a major component of the agenda.



... AND THIS IS UNDERWATER TECHNOLOGY

With underwater technology we mean **technology that clearly contributes to the skills and capabilities vital for activities, which in whole or in part have the underwater domain as their prime sphere of operation or study.** The technology embraces, for example, materiel, systems and methodology.

The water surface and seabed are included in the underwater domain, because what takes place on the surfaces affects whatever is in the water volume.

SOCIETAL BENEFITS OF UNDERWATER TECHNOLOGY

Underwater technology constitutes a fundamental prerequisite to the selection, preparation and implementation of projects related to ocean resource utilization, safety and environmental management. The *societal benefits* of these activities can be divided into:

- **resource utilization** – for instance, extracting gas, oil and minerals, as well as producing renewable power from wind, wave, sun and tidal waters, and the acquisition of aqua cultural and marine biotechnological products;
- **safety benefits** – safeguarding sea lines of communication and monitoring movements in, on and under water and also – with effective force – securing both them and territorial boundaries;
- **infrastructural benefits** – having the knowledge necessary for the construction of bridges, harbours and offshore installations such as energy power stations as well as pipelines and cables. These can also be utilized in similar land-based projects like mining;
- **environmental and climate benefits** – to measure and analyse physical, chemical and biological quantities under water with an aim to better understand the underwater environment and to tackle future challenges.

Innovation that results in a new, cost-effective technology will have a great significance for the realization of all these societal benefits. Furthermore, a well-functioning underwater innovation will contribute to societal benefits in the form of academic activities and industrialization, which will generate job opportunities and export revenues.

Sweden's potential to *realize these societal benefits* can be viewed from four perspectives:

- **capability** – our ability to maintain necessary basic functions in society, both civil and security & defence, and the opportunities to deliver effective results in this context;
- **partnership** – the ability to collaborate, inside and outside the innovation sector, in order to restore capabilities and deliver efficiency and synergies within innovation;
- **competence** – how to ensure that necessary knowledge, strengths and skills required are available when needed (including methods and processes);
- **legislation** – how to ensure that laws and practices do not create unnecessary obstacles for the innovation sector, especially in the context of anti-competitive practices.

In chapter 1 we will examine these perspectives and identify the key challenges.

ENABLING TECHNOLOGY AREAS

In order to facilitate these benefits, the Swedish innovation sector for underwater technology intends to focus on a number of specific technology areas where we have internationally viable competence and good opportunities for competitiveness. The technology sectors we have currently prioritized are:

- **vehicle engineering;**
- **construction engineering;**
- **energy technology** (production and use);
- **system development and integration;**
- **underwater communication, sensors** and **signal processing**;
- **robotics** and **autonomy;**
- **data analysis, modelling** and **software development;**
- **mechanics** and **material engineering;**
- **hydroacoustics** and **magnetics;**
- **human-system interaction;**
- **diving technology.**

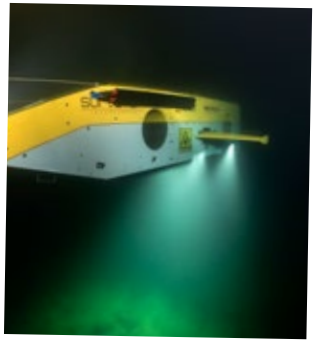
Some of these competencies are unique to the underwater technology sector, whereas others are shared with many other Swedish innovation areas. The underwater environment often demands exceptional requirements, with the result that the underwater technology innovation area has the potential to contribute to the whole innovation system.

Examples of technology developed in Sweden

Sweden has a recognized position in a number of markets. Here we list some of the products that have contributed to this achievement.

Wave energy converter with linear generator from **Sea-based.**

UMISS Mk II, multisignature platform from **Polyamp** for measuring underwater signatures.



MMT's integrated system for high-resolution inspection and mapping, **Surveyor Interceptor.**

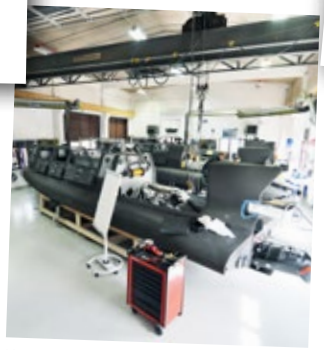
Roxtec seals for cable and pipe penetrations in bulkheads and decks for protection against fire, water ingress, gas, and other operational hazards.

ROHCV, remotely-operated underwater vehicle from **Saab** for environmentally-friendly cleaning of ships' hulls without the need to drydock vessels.

DeepEye, portable and hull-mounted Side Scan Sonars, interferometric and multibeam systems from **DeepVision.**

Poseidon SE7EN, a fully-enclosed, automated rebreather apparatus with unique software technology and patented oxygen sensor functionality..

Sensors from **FOI** (Swedish Defence Research Agency) for the measuring, amongst others, of particle motion in water.

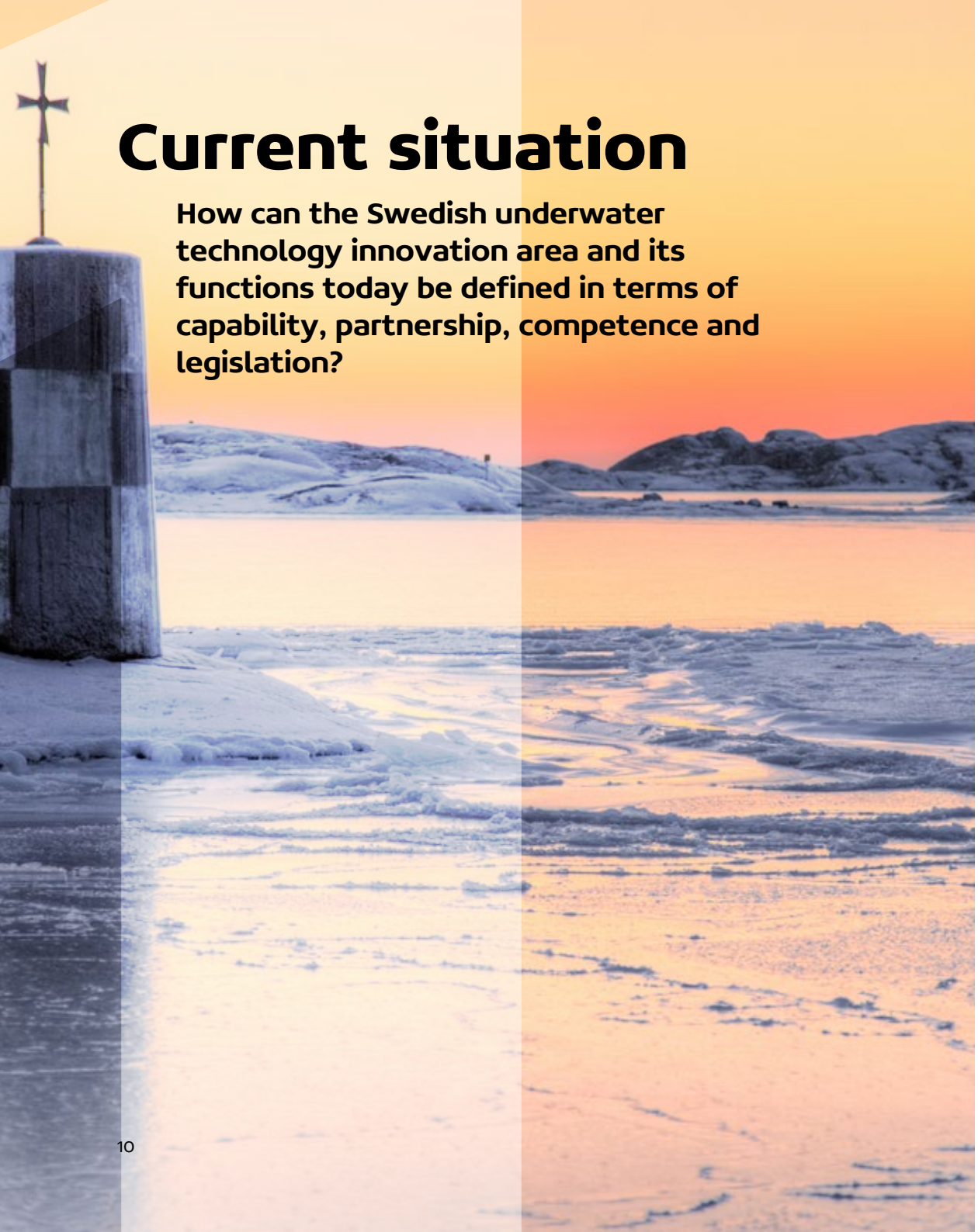


JFD Sweden's hybrid surface and subsurface vehicle, **Seal Carrier,** for military special forces.

Uppsala University's marine current power station, river-bed-based vertical axis turbine with a direct-driven permanent magnetized generator.

Current situation

How can the Swedish underwater technology innovation area and its functions today be defined in terms of capability, partnership, competence and legislation?



CAPABILITY

With capability, we refer to the ability to participate with Swedish competence in innovation applications and to deliver effective results in this context. The Swedish underwater technology capability can be viewed from a number of angles. In this agenda, we focus on *the globalized market, the potential for benefits and external and internal preconditions for innovation.*

Globalized market

In today's globalized world, Swedish innovation areas are becoming adapted to an increasing number of conditions imposed by the international arena. The underwater technology sector has prevailed due to a relatively small and domestic market in a relatively globalized context. But as a result of the general trend toward globalized markets, even this sector is being forced towards an increased internationalization.

It is becoming increasingly important for actors in Sweden to create an internationally competitive position to win contracts. To take the lead in their area of expertise, actors must specialize and be ready, willing and

> It is becoming increasingly important for actors in Sweden to create an internationally competitive position to win contracts.

able to collaborate with other actors. The Swedish actors must develop competitiveness in partnership at a national level.

> **Challenge 1A:** The market value of Swedish underwater technology is not as high as it would be with the right preconditions. There is a need to organize to achieve higher efficiency, collaborate and exploit new interdisciplinary "bridges" between national strengths within the sector to reach critical mass. This will further realize the Swedish potential in the context of international competition.

Challenge 1B: The international market is exclusive and difficult to access for Swedish actors because the marketing and sales of advanced underwater systems requires national coordination between business, academia and authorities. A large part of the operational development takes place within specific sectors, which are difficult for technology developing enterprises to collaborate with, not least due to defence and IPR-related reasons.

Potential for benefits

The civil market, much of which is driven by the exploration and extraction of gas, oil and metals, entails offshore activities such as construction projects, mapping, seaweed cultivation and alternative energy extraction as well as recreation and an increasing amount of research primarily in environmental and climate-related issues. Swedish "maritime know-how" and the technology necessary to build it has great potential to be internationally requested to a degree far in excess of the current demand.

Sweden also has particularly good preconditions to excel within specific fields, for instance work in shallow complex environments such as the Baltic Sea. This excellence is a distinct advantage that gives impetus to good practice within the underwater sector. However, these special areas are not always exploited to their full potential and innovations do not always reach the market.

The security & defence market is dominated primarily by the development of submarines, mine-countermeasure systems, mapping and reconnaissance systems, sensor systems for surveillance as well as ordnances. Comparable to the aviation sector major security & defence development projects, particularly submarines, have created direct civil benefits, in the form of technology dissemination and indirectly in the form of competence building and transfer.

On the defence market Sweden is a nation well known for its generally high level of technological expertise and for the systems and know-how it has developed within the field of shallow water warfare. Despite this fact, Sweden has – with certain exceptions – had limited export success with defence materiel within the underwater sector. This can be partly explained by the fact that there is a political aspect to defence related trades. Another inhibition is that Sweden is not in a position to fully offer comprehensive solutions embracing civil research and education associated with universities and colleges as well as security & defence research. Such solutions are impeded by their current tenuous connections with the rest of Swedish civil industry.

From neither a civil nor a security & defence perspective does Sweden assert sufficient control of the underwater domain. Such control is a prerequisite for a nation's ability to "oversee the integrity of its waters". Particularly to assert national sovereignty and to safeguard sea lines of communication. But also to address the ecological challenges facing us and ensure the safety of underwater installations.

> From neither a civil nor a security & defence perspective does Sweden assert sufficient control of the underwater domain.

Challenge 2A: There is lack of a clear understanding of how the underwater technology sector can contribute to solving environmental challenges.

Challenge 2B: Sweden needs to maximize efforts and strengthen its international competitiveness by way of increased education activities at all levels within underwater technology, maritime-related science, and their applications.

Challenge 2C: From a defence perspective, Sweden needs long-term research and technology development of materiel and capabilities for surveillance, mapping,

ACTORS IN SWEDEN

Within the context of NRIA-U, an estimate has been made of the underwater technology sector's actors and their size in Sweden:

- **Business, consisting of large and small enterprises** generating an annual turnover of approximately SEK 5 billion within the underwater technology sector, probably more than 50% thereof exported;
- Around 15 **authorities** are involved, with varying degrees of interest in the underwater sector;
- Around 20 **universities, colleges, institutes and academic centres** have varying levels of interest within the underwater sector.

These are estimates. Publication of more detailed data is planned on completion of a future survey of the underwater technology sector.

The figures may appear small in a national innovation context, but the return on expenditure increases by virtue of the fact that in many cases the underwater technology sector is an enabler for other areas, which generate higher revenues and, in some cases, unique capability building initiatives. Despite the small numbers, Sweden has a very high level of expertise and is well positioned for expansion within an area that can be regarded as an unexploited resource.

control and advanced reconnaissance with regard to the special conditions that prevails in the Baltic Seas.

Challenge 2D: Sweden should identify national preconditions within which we have a comparative advantage over our rival nations.

Challenge 2E: Technology and know-how for control of the underwater domain should be enhanced and based on a dual-use perspective.

External preconditions for innovation

Within Sweden there are many competent developers, manufacturers and demanding users of underwater technology. Yet compared with many of our competing countries, the Swedish market is fragmented. Sweden often lacks the focus on national competitiveness that is essential for the creation of the technology enterprises needed to be considered eligible for participation in international collaborations. Neither is there a functioning coordination between the actors' activities nor coordinated financing or a transparent and coherent responsibility for underwater issues at a political and authoritative level.

> Within Sweden there are many competent developers, manufacturers and demanding users of underwater technology.

Fragmentation is evident, amongst others, by the fact that the engagement and responsibilities for the authorities differs which results in the following consequences:

- difficulties for individual actors to participate in collaborative projects because, the actors are isolated and therefore "weak";
- difficulties for individual actors to keep track of potential financing opportunities;
- difficulties for decision-makers to get an understanding of the sector and its potential, thereby recognising the need for financing and national initiatives;
- difficulties in creating a basis for providing competence;
- failing export due to difficulties in offering a coherent national solution;
- lack of Swedish long-term sustainability in an international context that results in difficulties in providing comprehensive measurement data, which is required for establishing a unique environmental knowledge.

This fragmentation produces a low risk appetite and reluctance among Swedish authorities and companies to take on challenges. Access to venture financing is low compared to that of underwater technology sectors abroad. This may be explained in part by the long processes related to the underwater technology sector, which frequently leads to long time interval between investment and return; the present project-focused financing model are not always suitable for the demands of underwater technology.

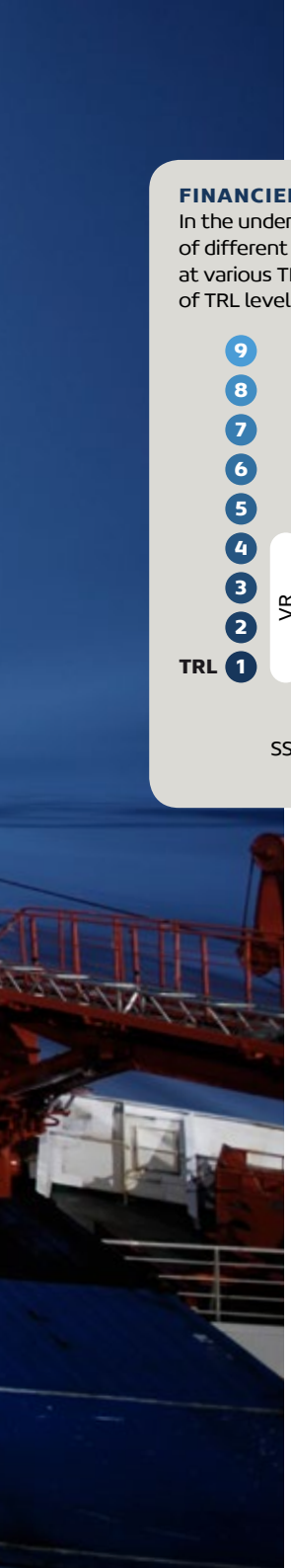
Sustainability in the Swedish innovations suffers from the fact that Swedish underwater research does not cover sufficient range on the TRL scale. One reason is that product development is required to commence with an acceptable level of risk, that is on a high TRL-level. Even commercial actors have problems in achieving sustainability because the many actors (public sector and financiers) in many cases lack a joint strategy. Furthermore, accessibility to and the coordination of resources in terms of test facilities, vessels, measuring equipment and the like could also be improved.

Regarding the matter of coordination between civil and security & defence activities, competence and dual use aspects should receive particular attention because a clear division between the two no longer exists. Increased civil efforts have in the broad sense a great potential to strengthen the defence sector and vice versa. The necessary sharing of knowledge is not only a question for the underwater technology innovation

MARITIME STRATEGY

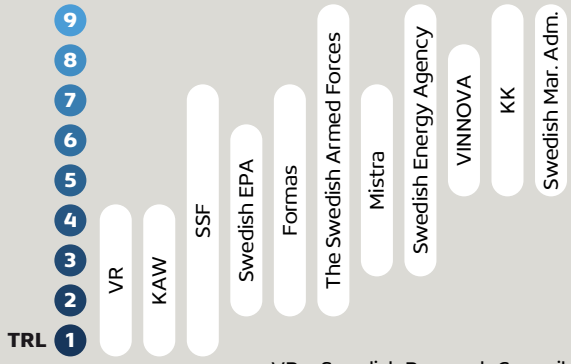
During the year 2015, the Swedish government published a maritime strategy for activities on the sea, in the sea, and activities that are dependent on resources from the sea. The aim of the maritime strategy is to focus on maritime activity and maritime economy. The document does not explicitly mention underwater technology or the underwater domain but does emphasize the importance of knowledge of the sea's living resources and characteristics, as well as composition of the sea bottom. The latter related to mineral extraction and development opportunities for wind, current and wave-based energy.

www.nria-u.se/maritimestrategy



FINANCIERS

In the underwater technology sector there are a number of different financing institutions, who support activities at various TRL stages. Some financiers span a large range of TRL levels whereas others focus on a specific scale.



VR = Swedish Research Council
KAW = Knut and Alice Wallenberg Foundation
SSF = Swedish Foundation for Strategic Research
KK = The Knowledge Foundation

area, but also very much for the governing ministries and authorities.

Challenge 3A: The Swedish underwater technology sector is fragmented. The actors are uncoordinated and have an inadequate capacity to achieve efficiency and generate synergies. This leads to an inefficient innovation chain.

Challenge 3B: The political leadership needs to bring together the ministries responsible for underwater technology sector as well as facilitate a cooperation between different authorities.

Challenge 3C: Sweden needs to take long-term action to establish overall knowledge of the state of the sea.

Challenge 3D: New business models for high-risk innovation procurement are needed, which embrace the underwater technology sector in its whole and where actors are well coordinated.

Challenge 3E: Infrastructural resources, test and demo facilities should be made available on a national level. These should be coordinated and to some extent newly developed.

Challenge 3F: Defence authorities should acquire a better understanding of on-going national civil activities within the underwater sector and thereby make use of dual use opportunities.

Internal preconditions for innovation

Sweden has the prerequisites for strong and fast innovation chain for a number of reasons. First, we have a relatively non-hierarchical culture prevailing within enterprises, authorities and academia; secondly, because there is an interest in developing new technology and to apply it and thirdly, there is a tradition to think 'new'. This means there is a firm foundation on which innovation can thrive and be received by the actors at management level.

To ensure effective innovation, the involved actors have to take responsibility for coordination. According to the fact box on page 6, innovation is defined as new ideas that results in a proven product, service or process on a market. An effective innovation will require that the innovation chain is unbroken.

Interruptions in the innovation chain, both temporary and permanent, usually occur in association with the "hand-over" between two actors. For example, when research results are evolved into product and service development the not very uncommon gap in the innovation chain is known as the "valley of death". The problem is usually linked with a lack of opportunities to finance demonstrators, with which

AVBROTT I INNOVATIONSKEDJAN

Normal interruptions in the innovation chain are between academia and institutes or institutes and business. These transitions must be secured.

the research technology is both tested and demonstrated.

The "Valley of death" and other similar gaps in the chains results in innovations not being completed and ultimately invested capital generates an unnecessarily low added value. The fact that the phenomenon is so frequent is a contributing factor to the low risk-taking discussed on page 12.

Challenge 4A: Innovation within underwater technology innovation chains must be uninterrupted to enhance the efficiency of the innovation and maximize its international competitive edge. Any gaps in the chain resulting from a lack of funds or coordination should be filled in by way of appropriate financing models.

Challenge 4B: Secure financing specifically aimed for "hand-overs" between academia and business should be made available for the development of demonstrators.

Challenge 4C: The incentive of actors to take risks within the innovation area, in the form of financing and taking decisions, needs to be strengthened.

PARTNERSHIP

Partnership is about clustering to create effective innovation. This is illustrated with the following three aspects: international partnership, national partnership between the innovation area and "external" actors and national partnership within the innovation area.

International partnership

In the globalized world the opportunities for Swedish innovation is often found within international partnerships. An important factor is how competitor countries run their innovation chains and the conditions they apply. Swedish innovation needs to have at least the same favourable conditions as actors in other countries to ensure that Swedish competitiveness remains high.

Actors in Sweden have a substantial international network and are engaged in a number of research projects and international committees within the underwater technology sector. Swedish business and authorities also participate in a number of projects related to the underwater sector within the framework of the European Defence Agency (EDA).

In order to achieve progress, these international partnerships need to be further strengthened, coordinated and given a higher profile.

Challenge 5A: The general conditions for Swedish participation in international development projects within the underwater sector need to increase, not least through active participation in European cooperation projects within the framework of, for example, Horizon 2020, EDA and structural funds.

National partnership – between the innovation area and external actors

Swedish underwater innovation have to operate as one single entity to be internationally competitive. All relevant actors should be able to contribute to innovation. However, there are often major differences in the conditions for various types of actors. For example, small and medium-sized enterprises – which are generally identified by the political leadership as the category of actors with the best potential for innovation – find it difficult to participate because the required self-financing limits their involvement. For this reason, there is almost a total lack of innovation-partnership activity among small and medium-sized enterprises. The same applies to underwater activities at the FOI (Swedish Defence Research Agency); in the absence of funds for self-financing, obstacles are created for participation in innovation. These critical actors require support to be able to participate in the innovation process.

> There is almost a total lack of innovation-partnership activity among small and medium-sized enterprises.

For effective innovation, ideas and technologies at different TRL levels have not only to be able to flow seamlessly between the innovation area and external actors, but also between the various innovation areas. The underwater technology innovation area has the same need for good conditions for innovation mechanisms – such as multi use, disruptive innovation and spin-in/off (see fact box) – as many other innovation areas. Further, the underwater technology innovation area has to be more active in bringing user experiences to the business community and academia.

Challenge 6A: The political understanding that small and medium-sized enterprises are often epicentres for innovation must be manifested by providing financial support for these actors. This is important when self- and co-financing is required.

Challenge 6B: Collaboration between the different innovation areas needs to be formalized to ensure it can be conducive. Collaboration should be possible at all innovation chain levels, embracing academic and business actors alike.

Challenge 6C: Collaboration between the innovation area and external actors (Triple Helix) should be conducted in a conducive manner.

Challenge 6D: Mechanisms that create preconditions for multi use should be in place, for example, general knowledge of opportunities and functional financing models.

Challenge 6E: Preconditions for disruptive innovation must be enhanced, so that the underwater technology innovation area is able to benefit from research results, which originate from other areas.

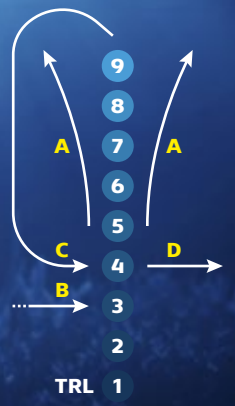
Challenge 6F: Dual use collaboration between civil and security & defence innovation should be strengthened.

National partnership – within the innovation area

The "valley of death", the hand-over stage between academia and business, is a common cause of interruption in innovation chains, with no exception for the underwater domain. One of the solutions is to enable an improved financing of demonstrators, which will serve as a bridge that takes research results into product development phase. But there are many constituents that play a part. In general, all actors in the innovation chain have to be aware of their role as well as the roles played by other actors. Likewise, the relationships between the actors have to be clearly known. The map of an innovation's journey from concept to

MULTI USE, DISRUPTIVE INNOVATION, USER FEEDBACK AND SPIN-IN/OFF

Multi use (A) is when the innovation chain – low on the TRL scale – is common to product and service development within a number of different areas – high on the TRL scale. An instructive example is dual use where civil and military applications are based on the same innovation. Swedish innovation needs to take lead when an innovation chain shows potential for creating benefits in other areas, or when needs from different market can be met with innovations that start in a common chain.



Introducing ideas and results developed in one innovation chain into another is referred to as **disruptive innovation (B):** the development does not take place in stages on based of past experiences but with the introduction of technologies, materials, methods, processes and the like, which are completely new to the sector. It is especially important for small and medium-sized enterprises to be able to deal with disruptive ideas, but equally so for those actors which operates inefficiently. Often due to high risks or deficient networks.

To work properly, an innovation chain should be open to **feedback from the end users (C),** who downstream will benefit from the product. This place high demands on the actors in the innovation chain to have methods for assessing the feedback and bring them into the innovation process. It is essential to be capable of coping with the so-called **spin-in (B, C)** from external processes, as well as to be able to deal with **spin-off (D).** The latter requires mechanisms for separating results within the innovation chain.

product needs to be drawn and made freely available, and appropriate preconditions has to be in place to ensure the best transition from research to product.

> **Challenge 7A:** The Swedish underwater technology innovation area needs to be mapped. All actors have to be aware of both their role and relations to other actors. This is a prerequisite generating increased opportunities for effective innovation.

COMPETENCE

Competence is of major concern for all innovation systems. Here the three following aspects are discussed: how competence influences the preconditions for capability, postgraduate education and academic careers, and undergraduate education offered by colleges.

Preconditions for capability

For Sweden to be able to compete in an international context, efforts have to be concentrated on a limited number of prioritized technology areas, as outlined earlier, within which Swedish companies will be able to place themselves in the forefront and at times even secure a leading position. This prioritization should not only aim at establishing competitive positions in already mature areas where future growth is expected, but to reflect the strengths that Sweden already possess, for example innovation potential, geographical conditions and enabling technologies such as communications

SIMILARITY WITH COMPUTER GAMES

The similarity between playing computer games and operating a ROV/AUV is striking. For example the user interface for computer games is similar to the controls for ROV systems. In Sweden there is a significant competence in the development of computer games which, given the right preconditions, can be allowed to spill over into the underwater technology sector.

technology, computer vision or advanced material technology.

Similar to other technology areas in Sweden, it is of interest to prioritize competencies at high system level. System integration is a discipline that is growing in significance within underwater technology, and where

> System integration is a discipline that is growing in significance within underwater technology.

methods and system support is increasing in the development stage.

To be competitive Sweden needs to actively produce and maintain competent personnel throughout the whole innovation chain, not at least to be able to take full responsibility of the whole innovation chain, from idea to product/service on the market. Even if it will be necessary to go abroad, Sweden must have the competence in these areas to ensure that we can function as a qualified purchaser.

A product or service on the market has to satisfy the users' requirements in order to create high demand. Pull from the market will provide precondition for the innovation chain. There is also a need to ensure that Sweden is leading within best practice for products and services produced, thereby ensuring that the feedback from the market is based on the best available methods. In order to reach the full potential of a product, efficient methods and techniques have to be developed. Development of methods is however beyond the scope of what small and medium-sized enterprises can manage; arrangements for support from end users are required.

The security & defence area of underwater technology poses particular challenges, due to the fact that the underwater system capability is one of Sweden's two *national essential security interests* (see fact box). The nation's capabilities in the underwater domain are therefore politically identified as prioritized. Sweden need to create the best possible preconditions to maintain these capabilities.

National competence for sustaining capability is not only of security and political interest. The security & defence capability requires a national industrial capability, and this adds to the Swedish competitiveness. An industrial capability that is sufficient for sustaining a security & defence capability is

> The nation's capabilities in the underwater domain are therefore politically identified as prioritized.

a strong indicator of an ability to compete on the civil market.

The national competence have to be long-term in order for it to be sustainable. In the long run, it is cheaper to sustain a capability over time than to create it repeatedly in cycles. It will be impossible to regain competence at a later phase at a reasonable cost, if it is lost. An equivalent vicious circle also exists in the civil sector: lack of funding ultimately results in inadequate preconditions for maintaining the capability.

> **Challenge 8A:** Sweden have to strengthen its competence in underwater technology, based on a number of selected technology sectors. The prioritization should address innovation activities at high system level.

> **Challenge 8B:** Sweden must strengthen its international competitiveness by way of an increased education activity within the area of underwater technology.

> **Challenge 8C:** Sweden must contribute to best practice within the underwater technology area.

> **Challenge 8D:** In a world where resources are limited and demands grow, development of new and cost-effective methods are required.

> **Challenge 8E:** Swedish competence for maintaining industrial and security & defence capabilities should be guaranteed. Sweden needs a long-term strategy in order to maintain this critical competence.

Postgraduate education and careers

The efficiency of innovation is intimately associated with facilitating the smoothest possible transfer of know-how and experience. In many cases, the transfer occurs when people physically relocates within the innovation chain. A fragmented and diversified sector will make the transfer complicated.

Furthermore, the Swedish underwater technology sector is interdisciplinary embracing many diverse, widely-differing branches of knowledge. Whilst this is positive from a partnership perspective, it also makes it difficult to develop an academic career, which may require a change of research discipline. This will result in dilution of the underwater technology as a subject and places high demands on acceptance between academic disciplines. A properly functioning academic system is a prerequisite for appealing and attracting the best people. Academic career opportunities are of critical importance for Sweden's competitiveness.

> Academic career opportunities are of critical importance for Sweden's competitiveness.

Within underwater technology one can be a specialist within one discipline, or a generalist with a high level of systemic approach. The generalist role is often difficult to maintain in a fragmented environment although the need is high.

An identical career problem prevails within the business sector for the same reasons as those described for academia. An effective innovation chain is conditional upon knowledge and competence being able to flow unhindered within the chain, even amongst the external actors.

ESSENTIAL SECURITY INTERESTS

In the government's bill 2013/14:99, underwater capability is identified as an essential security interest: "Underwater capability constitutes an essential security interest and retention of the skills base is necessary to sustainably secure this capability for the Armed Forces."

Sweden has two essential security interests. The second is the fighter aircraft system.

INITIATIVES FROM ACADEMIA

Until now, concerted postgraduate education in underwater technology has been non-existent in Sweden. The subject is also characterized nationally by a clear absence of academic nodes. However, a change of this situation is underway by way of initiatives for the formation of clusters for science and engineering.

The **KTH Cluster for Underwater Technology (CUTe)** was established in 2015 by **KTH (Royal Institute of Technology), Saab** and **FMV (Swedish Defence Materiel Administration)** with the goal of gathering Swedish underwater technology competence in order to meet future requirements from business, academia, society and to satisfy student interest for the subject.

The project **Mobile Underwater System Tools** was established in 2014 based on an allocation for the provision of an autonomous underwater vehicle as a Swedish national resource primarily specialized for long expeditions in arctic climates, for example, beneath the polar caps.

The city of Karlskrona is home to the **Armed Forces Diving and Naval Medicine Centre (FMDNC)** and **Blekinge Institute of Technology (BTH).** Today, these activities have strong connections with underwater technology in the form of unique demonstration and simulator environments. **BTH** has signed technology partnership agreements with the **Swedish Navy** and with **business enterprises** (for example, **ABB**) with the aim of undertaking joint course development and applied research projects where the results will quickly be put to serving beneficial use.

In Göteborg, collaborations are being discussed between **Göteborg University, Chalmers, Stockholm University, Lund University, Swedish Maritime Administration (Sjöfartsverket)** and the **business sector** regarding the establishment of education in marine surveying, both at masters level and as certified continuation training. **Region Västra Götaland** and the **business sector** will jointly finance a professorship for two years.

As a result of the establishment of these groups, Swedish academic postgraduate and undergraduate educations in underwater technology enter a new phase of a defined subject areas and better career opportunities.

Challenge 9A: The transfer of know-how and experience by way of physical relocation of people, for example through career paths, needs to be simplified. This applies within academia, business, authorities, as well as between them.

Challenge 9B: There is a need for a common, or at least in parts coordinated, postgraduate education between scientific disciplines and engineering.

Undergraduate education

The underwater technology sector is urgently in need of competent people who have studied appropriate subjects in their undergraduate education. Underwater technology does not exist as a specific academic discipline in Sweden, which partly explains

> Students in the process of choosing an educational path will have no way of knowing that the underwater area exists.

why there is no undergraduate education program. Students in the process of choosing an educational path will have no way of knowing that the underwater area exists. Furthermore, coordination between related subjects, for example general technology, economics, biology, physics, electronics, mechanics, and vehicle engineering is inadequate presenting yet another obstacle for students to be introduced to the area. At present, there is no available education for students who wishes to attain the generalist competence mentioned earlier.

Challenge 10A: The underwater technology sector needs an increased recognition among students in order to attract them, thereby ensuring the continued growth of competence.

Challenge 10B: Education is fragmented and coordination between them is inadequate.

Challenge 10C: Sweden does not only produce insufficient numbers of specialists within the underwater technology sector, but also insufficient number of generalists.

LEGISLATION

The access to the innovation market, which often leads to a competitive position, is influenced by laws, especially legislation that relates to security and defence as well as national laws and their interpretations which impede competition.

Relevant legislation

In many cases, activities in the underwater technology innovation area are subject to legal regulations. These often inhibit the use of the innovation. Thus the development of the innovation will be associated with a risk since the use will be hindered by the regulations. An example within the underwater technology sector are autonomous vehicles where national and international legislation have not kept pace with the rapid technological development. The result is that the underwater sector does not have up-to-date legal framework that enable the innovation to reach the market.

In Sweden, the responsibility of the underwater sector is fragmented on both ministerial and authority levels. This is a drawback compared to the other Swedish innovation sectors, because it leads to a blockage that is hard to break.

Challenge 11A: Legislation needs to be reviewed to make it relevant and adapted to the new technology. Furthermore, legislation needs to be flexible so that it can allow for technological development that, under the right preconditions, will be unimpeded and deliver opportunities that can speedily be realize to their full potential.

National differences – barriers to competition

The preconditions for winning international procurement contracts vary between different countries depending on national legislation. Small and medium-sized enterprises can be negatively affected when lack of a driving domestic market and lack of possibilities to test systems in national waters make international collaborations the only possible solution. Small and medium-sized enterprises often encounter difficulties when they need to both collaborate with other actors and safeguard their intellectual property rights.

A striking example is measurement data that provides information regarding environmental conditions and bathymetry and can be produced with modern underwater technology; the distribution of data to actors such as offshore industries, enterprises within renewable energy and marine cultivation, which undertake installations on the seabed, and marine archaeologists, is impeded by the fact that the underwater domain is of national security interest. This status embraces all activities, which involve surveys of the seabed, even for purely civil purposes. The management of marine data will be eased due to a new law treating the protection of geographical information, which will come into force in 2016. Still, in line with the consultation views of several authorities, it is believed that there are still improvements that need to be made.

However, all the limitations in the forms of laws and legal frameworks are not of a juridical nature. Obstacles can also occur in the form of standards. This is where Sweden currently plays a minor role as it does not participate in the international standardisation process to the extent that is justified by our innovation potential. Increased participation in this work would provide us with an opportunity to influence requirements demanded of new products and services to a much greater extent.

Challenge 12A: National differences in legislation need to be rationalised so that actors in different countries have the preconditions to compete on equal terms.

Challenge 12B: Actors, particularly small and medium-sized enterprises, need to be guaranteed that they can retain their intellectual property rights when they collaborate with other actors.

Challenge 12C: Marine measurement data from the underwater domain are currently restricted for defence and security reasons, but should be made accessible for civil actors. Even after the planned change of legalisation to be enforced in 2016, the accessibility to data has to be improved.

Challenge 12D: Sweden needs to increase its participation in international standardisation activities. National objectives need to be identified.

Vision and objectives

What would the future look like if Swedish underwater technology innovation was given the best preconditions? In which areas will Sweden be a world leader, and how will we get their? Here we present a vision for 2030 and objectives for 2020 and 2030.

VISION 2030 = OVERCOME CHALLENGES

In the year 2030, Swedish underwater technology will be a leading actor on the global market as a consequence of targeted activities at establishing a position and creating competitiveness for underwater technology actors in Sweden.

Sweden has secured unbroken innovation chains and ensured that Swedish innovation is based on national areas of expertise and strength and that these areas are further strengthened continuously. Sweden can demonstrate the commercial potential of research results, assemble actors in joint

OBJECTIVES 2020 (SHORT TERM)

2020:1 A national research network within underwater technology is established consisting of academia, institutes, business and authorities. The network is used to exchange information and experiences, ensure the continuity of the innovation chain, and monitor, evaluate and update NRIA-U.
Addresses challenges: all

SEE CHAPTER 1

2020:2 A national research framework program within the underwater sector is established, National Underwater Technology Research program (NUFP) financed by authorities (civil and defence) and business.
Addresses challenges: 1AB 2ABCDE 3ABCDEF 4AB 5A 6ABCDEF 7A 8ABDE 9AB 10ABC 11A

2020:3 The research-financing authorities have accepted the prioritized technology areas as central.
Addresses challenges: 1AB 2BCDE 3ABCDEF 4AB 5A 6BCDEF 7A 8ABDE 9AB 10ABC

2020:4 Actors within the underwater technology sector have coordinated their research and development projects

projects and create preconditions for actors in Sweden, enabling them to participate in international innovation projects.

The best possible partnership with the innovation area is assured due to maximized dual use/multi use and functioning mechanisms for disruptive innovation and spin-off. All actors within underwater technology domain are aware of their position, relevance and significance in the innovation chains, and financing is effective and coordinated.

Sweden has an education system that guarantees stable and adequately good growth of and access to competent personnel. There is a dedicated undergraduate education at college level within underwater technology, synchronised with the prioritized technology areas. Sweden has a long-term strategy for maintaining the competence required to guarantee the security & defence and business capabilities.

On the political arena, the underwater technology sector has got its own joint governance, and the relevant authorities have a common understanding for the sector. This creates national efficiency that ensures Swedish innovation actors are in demand. The legal preconditions for civil actors to compete on equal terms with actors in other countries are the best possible and Sweden plays a large and active role in international standardisation activities.

Coordination and monitoring of the sector is conducted via a partnership forum for underwater technology.

Sweden has through focused efforts on underwater technology contributed to achieving – in a measurable way – Sweden's environmental quality objectives, primarily with focus on the seas in balance, a living coast and archipelago, living lakes and waterways, limited climate impact, fresh air, and no contribution to eutrophication. The focus on underwater technology has resulted in opportunities to support the national maritime strategy, that is the *seas in balance* and *competitive maritime industries*.

resulting in the creation of research centres with a joint investment exceeding SEK 100 million. Activities are initially directed towards applied solutions with a strategic focus on enhanced capacity and competitiveness.
Addresses challenges: 1AB 2ABCDE 3ABCDEF 4ABC 5A 6ABCDEF 7A 8AB 9AB 10ABC 11A 12D

2020:5 Three national demonstrators for research and development within the designated competence areas are being developed with a joint investment of SEK 90 million.
Addresses challenges: 1AB 2ABCDE 3ACEF 4ABC 5A 6ABCDEF 7A 8ABCDE 9AB 10ABC

2020:6 Sweden has conducted a system study and a system demonstration of an underwater reconnaissance network in Swedish territorial waters with AUVs and other systems including a network node, undergoing pilot trials.
Addresses challenges: 1AB 2CDE 3AEF 4ABC 5A 6BCDF 8ABCDE 10BC

2020:7 Sweden has conducted a system study and a system demonstration of a network of underwater measurement stations for continuous environmental monitoring of Swedish territorial waters in accordance with EU environment objectives. A network node is also undergoing pilot tests.
Addresses challenges: 1AB 2ACDE 3ACE 4ABC 6BCD 8ABCDE 10BC

2020:8 Design of the next generation submarine (after A26) is underway together with the corresponding technology development of at least TRL 4 within the relevant areas of the prioritized technology sectors.
Addresses challenges: 1AB 2CDE 4ABC 6BCDEF 8ABCDE 10BC

2020:9 Sweden has an international leading underwater vehicle for environment and polar research operative as well as the related research program.
Addresses challenges: 1AB 2ABCD 3ACF 4AC 5A 6BCD 8ABCDE 10BC

2020:10 Sweden participates with academia, institutes and business in EU-financed research projects (for example, Horizon 2020) with funding of at least SEK 30 million annually.
Addresses challenges: 1AB 2ABC 3A 4A 5A 6ACEF 8BDE 10C

2020:11 Applications to the EU structural funds within the underwater technology sector have increased by 50 % since 2015.
Addresses challenges: 1AB 2ABC 3A 4AB 5A 6CEF 8BDE 10C

2020:12 The Ministries of Defence, Trade & Commerce, Education, and Environment & Energy take joint strategic decisions on how research and development within underwater technology can be supported.
Addresses challenges: 1AB 2ABCDE 3ABDEF 4ABC 5A 6ABCDEF 8ABCDE 9AB 10ABC 11A 12ACD

2020:13 One authority is designated as responsible for activities in the underwater domain.
Addresses challenges: 1AB 2ACDE 3ABF 4ABC 6BCDEF 8ABCDE 9B 10BC 11A 12ACD

2020:14 One research financing authority has primary responsibility for research financing of civil underwater technology and the competence to deal with the sector and support it with financing.
Addresses challenges: 1A 2ACDE 3ABF 4ABC 6ABCDEF 8ABCDE 10BC 12B

2020:15 The number of partnership projects between Sweden and other nations who have an interest in purchasing Swedish underwater technology has increased by 50 % since 2015.
Addresses challenges: 1AB 2CD 3AB 4A 5A 6C 8DE 9A 10AC

2020:16 There is a database of supply and demand within underwater technology innovation where actors effectively gain access to information about current and forthcoming business challenges.
Addresses challenges: 1A 2ACD 3A 3DF 4ABC 6ABCDEF 7A 8ADE 10BC

2020:17 A survey of actors within the Swedish underwater technology innovation area is conducted with details on turnover, number of persons employed and position in the innovation system.
Addresses challenges: 1A 2AD 3ABEF 4AB 6ABCDF 7A 8AE 10ABC

2020:18 There are at least 50 undergraduate students active within underwater technology at Swedish universities and colleges in close collaboration with research. Prioritized technology areas are central in the education. The sector attracts generalists and specialists within both engineering and science. Collaboration between academia, education and business is clear all the way to undergraduate level. Even foreign students are attracted by the education.
Addresses challenges: 1A 2ABC 3AF 4A 6BCDF 7A 8ABE 9AB 10ABC

2020:19 Sweden has internationally recognized research within human-system-interaction in underwater technology applications. Amongst others, procedures and technologies for secure and effective interaction between divers and ROV/AUV have been developed.
Addresses challenges: 1AB 2BCDE 3E 4ABC 5A 6BCDEF 8ABCDE 10BC

2020:20 Sweden has internationally recognized research with regard to reducing production costs for wave, current, tidal water and wind-based forms of energy making them more competitive for Sweden's energy systems.
Addresses challenges: 1A 2ABCD 4A 5A 6BCDE 8ABCDE 10BC

2020:21 Sweden has adopted the rules and best practice guidelines, which have been adopted internationally within the unmanned operations area.
Addresses challenges: 1B 2CD 3C 4AC 5A 6CF 8CE 10C 11A 12AD

2020:22 Sweden has adopted rules, which enable civil actors to conduct marine measurement for civil purposes, the results of which can be collated and disseminated and thereby made accessible to agencies and research.
Addresses challenges: 1B 2A 3BC 4A 5A 6CF 8CDE 10C 11A 12AC

2020:23 Sweden is a forerunner, based on common standpoints, in international standardisation.
Addresses challenges: 1AB 2CD 3A 4A 6BCDEF 7A 8ACE 10C 11A 12ABD

2020:24 There is a political plan for the reflagging of ships back to Sweden. With vessels under Swedish control, the opportunities for underwater operations will increase, whereby the innovation area will be strengthened.
Addresses challenges: 1A 2CD 3B 4ABC 5A 6BCF 8CE 10AC

2020:25 Sweden has developed procedures and technologies for operative diving with next generation rebreather systems.
Addresses challenges: 1AB 2CDE 3F 4ABC 5A 6BCDE 8ABCDE 10BC

2020:26 Sweden has sufficient skills and know-how within academia and industry enabling leading international actors to relocate central departments for underwater operations and installations to Sweden.
Addresses challenges: 1AB 2ABCD 3AE 4AC 6ABCEF 8ABCE 9A 10ABC 11A

2020:27 At least ten strong KPIs (Key Performance Indicators) have been identified which focus on how the underwater sector will contribute to the environmental quality objectives of Sweden and which of these objectives they address.
Addresses challenges: 1A 2A 3C 4A 6C 8ACE 9B 10C

OBJECTIVES 2030 (LONG TERM)

2030:1 Swedish underwater technology innovation is around 90 %, in terms of turnover, focused on a number of prioritized technology areas.
Addresses challenges: 1A 2CD 3AB 4AB 5A 6BCDE 8ADE 9B 10BC 12B

2030:2 The turnover of the business sector within the underwater area amounts to SEK 10 billion annually.
Addresses challenges: 1AB 2AC 4ABC 6AC 8E 9A 10AC

2030:3 The spin-off enterprises established since 2016 will have a turnover of SEK 1 billion attributable to investments in underwater technology.
Addresses challenges: 1A 2C 3D 4ABC 6AC 8E 9A 10AC 12B

2030:4 Academia within the underwater sector, with associated demonstrator environments will jointly generate revenues of at least SEK 250 million annually.
Addresses challenges: 1AB 2ABCDE 3EF 4ABC 5A 6ABCDEF 8ABCDE 9AB 10AC

2030:5 Universities in Sweden produce on average two postgraduate examinations annually within the sector.
Addresses challenges: 1A 2ABC 4AC 6C 8ABCE 9B 10AC

2030:6 Development and production of the next generation submarines continue in the relevant areas of the prioritized technology areas. These activities will be at a minimum of TRL 8, with a particularly high element of unmanned systems.
Addresses challenges: 1A 2BCDE 3DE 4AB 6BCDEF 8ACDE 10BC

2030:7 Autonomous underwater vehicles are operative in civil and security & defence contexts.
Addresses challenges: 1A 2ACDE 3CE 4ABC 6CDEF 8ACDE 10BC 11A 12A

2030:8 Sweden has established an operative underwater reconnaissance network in Swedish territorial waters where reconnaissance AUVs plays a major role.
Addresses challenges: 1A 2CDE 3CE 4ABC 6CDE 8ACDE 10BC

2030:9 Sweden has established an operative network of underwater measurement stations for continuous environmental monitoring of Swedish territorial waters in accordance with EU environment directive.
Addresses challenges: 1A 2ACD 3CE 4ABC 6CDE 8ACDE 10BC

2030:10 Laws are updated so that autonomous underwater vehicles can be routinely used.
Addresses challenges: 1B 2AC 3C 4A 5A 6CDF 8ACE 10C 11A 12AC

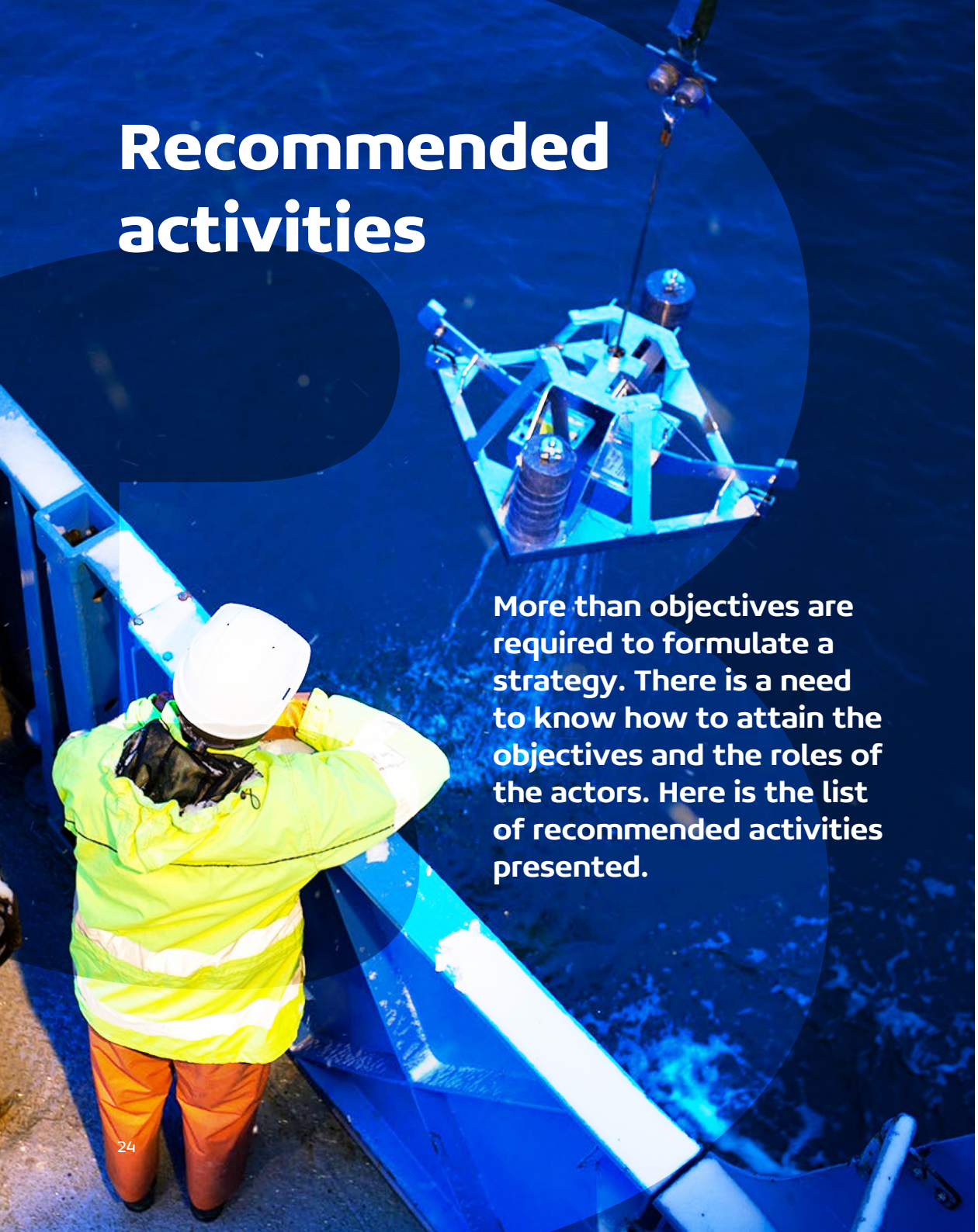
2030:11 Sweden is a world-leading partner in shallow water and ice-covered environments as well as coastal operations.
Addresses challenges: 1AB 2ABCDE 3E 4A 5A 6BCE 8ACDE 9B 10BC

2030:12 There are at least five Swedish-flagged, highly qualified offshore vessels for underwater technology assignments.
Addresses challenges: 1A 2C 3B 4ABC 5A 6BCDE 8CE 9A 10AC

2030:13 Divers and remotely controlled or autonomous vehicles can safely and efficiently interact in proven effective operations.
Addresses challenges: 1AB 2CDE 3E 4ABC 6BCDE 8ACDE 10BC

2030:14 Sweden's efforts and investments in underwater technology have contributed to – in a measurable way – the environmental quality objectives based on identified KPIs.
Addresses challenges: 2A 3C 4A 6C 8ACE 9B 10C

Recommended activities



More than objectives are required to formulate a strategy. There is a need to know how to attain the objectives and the roles of the actors. Here is the list of recommended activities presented.

1 PARTNERSHIP FORUM

We propose that: the innovation area for underwater technology organizes its actors in a partnership forum. The forum will deal with common innovation issues within the sector and instigate contacts with "external" actors such as politicians, decision makers, authorities, financiers, and with other innovation sectors. It is suggested that the forum organizes prioritized national competence networks at suitable locations to oversee that there is competence available to take ideas to the market.

Activities manged by the forum can for example be branch of industry events, joint trade fair participation, concrete partnership projects, joint applications and procurements, as well as annual conferences for the actors within the innovation area.

It is proposed that the activities of the forum are executed in a stepwise way starting with a common strategy, followed by a common platform, common demonstrators, joint programs, and joint products. Concrete measured values of the development are, for example, the number of enterprises (of varying size), number of joint projects, number of spin-offs, and number of products.

It is proposed that the forum owns and updates the National Innovation Agenda for Underwater technology (NRIA-U) and is responsible for ensuring that the actors within the innovation area secure a strong Swedish competitiveness in compliance with the agenda.

It is also proposed that the forum will be responsible for the partnership of the underwater technology sector with the aim to generate synergies and efficiency within Swedish innovation.

In addition to the aforementioned, it is proposed that the forum serves as a legislative body for consultation related to activities within the underwater domain.

First step to be taken by: the actors behind NRIA-U.

Addresses objectives: all identified objectives because the forum is assigned

SEE CHAPTER 2

the ownership of NRIA-U and responsible for monitoring of the objectives. Specifically 2020:1,3,4,5,8,9,10,11, 12,13,14,15,16,17,18,22,26,27 + 2030:2,3,4,7,11,14

2 PRIORITIZED TECHNOLOGY AREAS

We propose that: all internal and external actors in the underwater technology innovation area come together in an on-going effort to establish the prioritized technology sectors. Currently, the following sectors are identified:

- vehicle engineering;
- construction engineering;
- energy technology (production and use);
- system development and integration;
- underwater communication, sensors and signal processing;
- robotics and autonomy;
- data analysis, modelling and software development;
- mechanics and material engineering;
- hydroacoustics and magnetics;
- human-system interaction;
- diving technology.

This list is preliminary. The innovation activities proposed within the framework of NRIA-U will form the basis for adjustment of the list.

First step to be taken by: the proposed partnership forum for underwater innovation together with specific actors within underwater technology academia.

Addresses objectives:
2020:3,4,5,6,7,8,9,10,11,12,15, 18,19,20,25,26,27 + 2030:1,2,3,4,5,6,7,9,11,13,14

3 DEMONSTRATOR-FINANCING PROGRAMS

We propose that: a program for demonstrator development is launched at medium-TRL level that improves the preconditions for "productification" of available research results. Institutional activities need to be given an opportunity to assume an active role therein, even if academia and business need to participate in safeguarding the bridge over the "valley of death". The demonstrators we propose are:

- an **AUV demonstrator** for development of technologies related to underwater vehicles;
- a **system-integration demonstrator** consisting of subsystems and systems, for demonstration of operational efficiency, for example:
  - methods for securing less weather-dependent operations;
  - methods for reducing down time;
  - cost effective mine clearance;
  - effective monitoring and securing of underwater installations;
  - interaction between divers and ROV/AUV;
  - operational procedures for diving with modern diving equipment;
  - operator interaction with remote-controlled and semi-autonomous vehicles.
- a **measurement-station demonstrator** for environmental measurement and traffic monitoring.

First step to be taken by: the proposed partnership forum for underwater innovation.

Addresses objectives:
2020:3,4,5,6,7,8,9,10,11,12,15, 19,20,25,26 + 2030:1,2,3,4,5,7,8,9,11,13,14

4 NATIONAL UNDERWATER-RESEARCH PROGRAM

We propose that: a national research program (National Underwater Technology Research program (NUFP)) is created at a lower TRL level for coordination and financing of synchronized research activities.

First step to be taken by: Vinnova, with courtship from the proposed partnership forum for underwater innovation.

Addresses objectives:
2020:1,2,3,4,5,6,7,8,9,10,11, 12,13,14,15,18,19,20,25,26 + 2030:1,2,3,4,5,6,7, 8,9,11,12,13,14

5 COHERENT CONTROL

We propose that: all ministries, which have ownership of the underwater technology sector, collaborate in a formalized way with mandate, opportunity and motivation to take joint strategic decisions in matters which relate to the underwater technology sector. This applies to innovation significant to the underwater technology sector; including activities such as capacity, partnership, competence and legislation in order to realize the societal benefits to which underwater technology can contribute.

The involved ministries should then instruct their subordinate bodies to collaborate correspondingly. Special emphasis should be placed on collaboration between civil and security & defence authorities with the goal of creating clear responsibility for all activities within the underwater domain.

This is expected to result in an adjustment of willingness of risk-taking among decision making bodies, because pre-conditioning will change. A coherent strategy of the underwater technology sector will change the preconditions that in turn will decrease uncertainties both in number and significance.

Coherent control will imply that an inter-ministerial partnership is initiated in Sweden with the aim to establish a network for underwater surveillance of the Swedish economic zone both for civil benefits (environmental monitoring) and security & defence (territorial control).

First step to be taken by: Ministry of Defence, Ministry of Trade & Commerce, Ministry of Education and Ministry of Environment & Energy in partnership. The proposed partnership forum for underwater innovation can assume responsibility of initiating the work by convening the first meeting.

Addresses objectives:
2020:1,2,3,4,5,6,7,8,10,11,12,
13,14,15,17,18,19,20,21,22,25,26,27 + 2030:1,2,3,
4,6,7,8,9,11,13,14

6 MAPPING OF ACTORS AND ACTIVITIES

We propose that: the aforementioned proposed forum assumes responsibility for surveying of the underwater technology innovation area with regard to constituent actors (primarily authority dependent), competencies, roles, market segments, business chains, financiers, and legislation.

The result of this survey will give a clear indication of where the shortcomings in innovation chains are as regards the necessary flow of ideas, technologies and competence, and how financing can be enhanced through joint efforts.

Furthermore, the survey will include an identification of Key Performance Indicators (KPI) for the sector's capacity to contribute to Sweden's environmental quality objectives and identify opportunities to concretize the national maritime strategy.

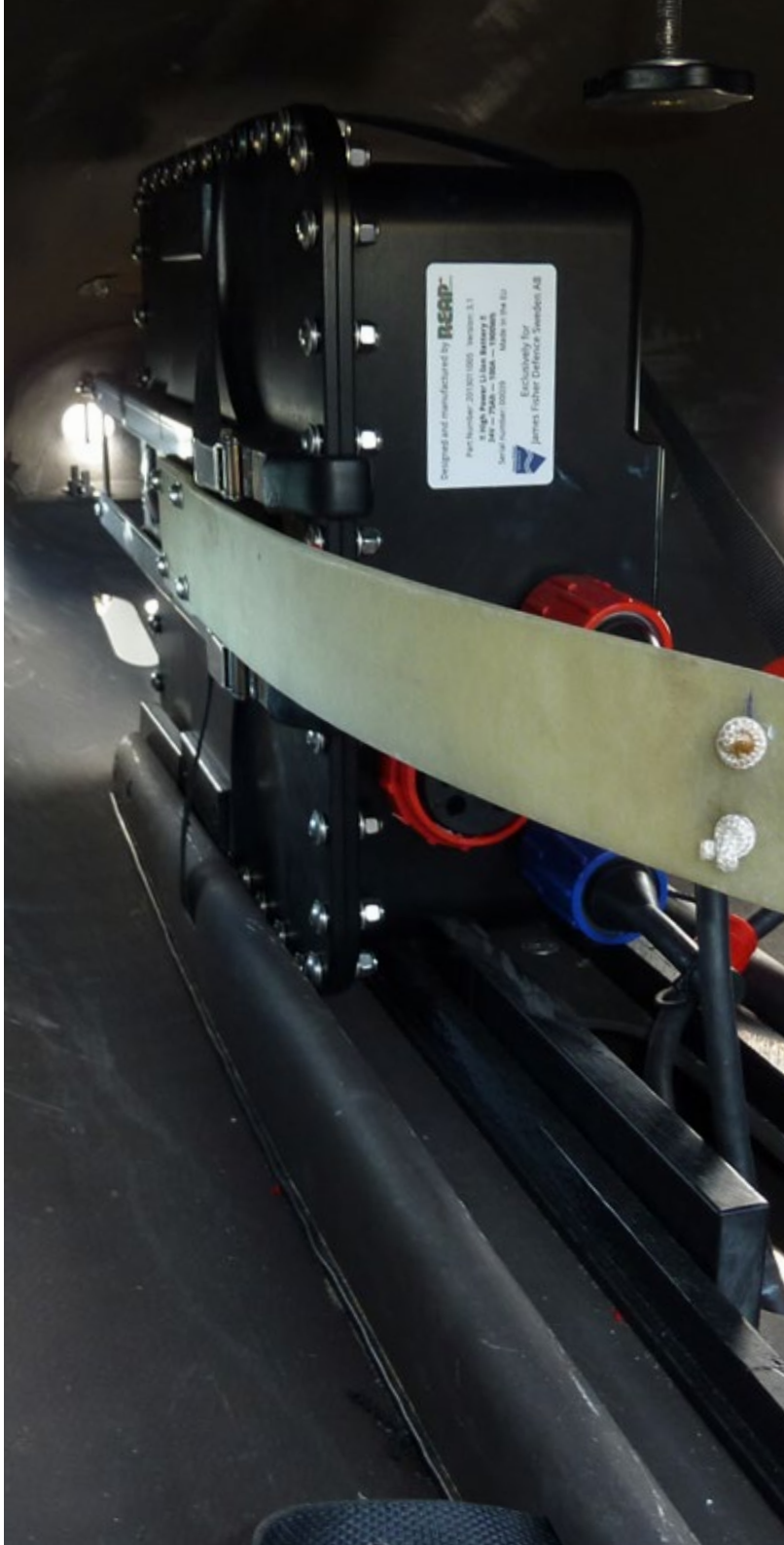
The results of the survey are expected to demonstrate the benefits of underwater technology innovation activities for Sweden within the areas of environment, security & defence, employment and export, for the relevant decision makers. They can also be used for marketing of the area to potential students.

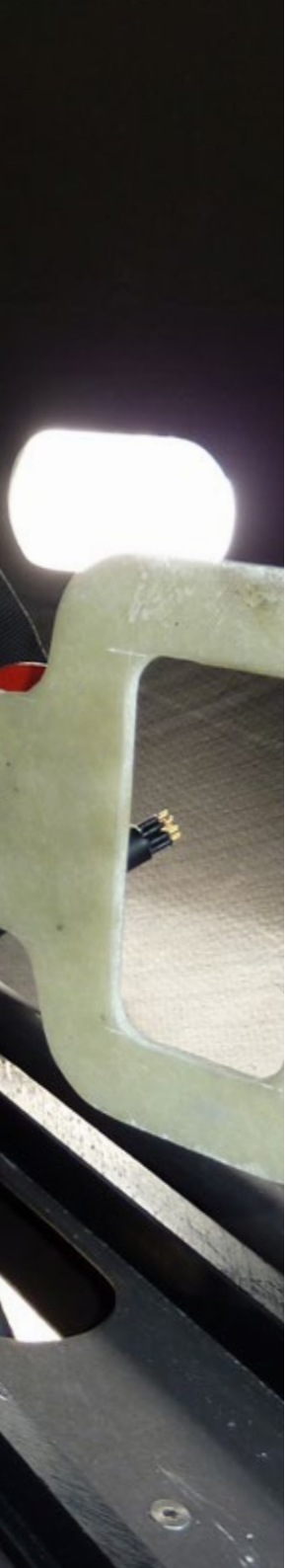
First step to be taken by: the proposed partnership forum for underwater innovation.

Addresses objectives: 2020:1,2,3,4,6,7,10,11
,12,15,17,
18,20,27 + 2030:2,3,4,14

7 TECHNOLOGY AND MARKET BANK

We propose that: a joint combined technology and market bank is established, where "push" (from the innovation chain) and "pull" (from the market) can meet. Not least small and medium-sized enterprises can take advantage of the bank to decide where to invest. Both "push" and "pull" are continuously monitored for identifying strategic possibilities to for long-term business opportunities and more short-term innovation activities, both which can guide the enterprises in accordance with the "oblique wave" principle.





The technology and market bank should, to be attractive, also include models for innovation, financing and intellectual property rights, which take the interests of all parties into consideration.

Typical constituent activities include technology seminars, requirement analyses in the form of meetings between standard authorities and suppliers, dissemination of information about available test facilities as well as demonstrators.

First step to be taken by: the proposed partnership forum for underwater innovation.

Addresses objectives:
2020:4,5,6,7,8,9,15,16,25 + 2030:2,3,7

8 COMPETENCE DEVELOPMENT

We propose that: preconditions for the development of coordinated undergraduate education with an underwater technical orientation are established, where the end-users of underwater technology have an influence on the content for best market adjustment and thereby preconditions for international competitiveness.

The conditions for coordinated postgraduate education are investigated simultaneously. Special emphasis should be placed on the potential for a joint or coordinated graduate school where strengths in interdisciplinary work are studied.

The opportunities for making a career needs heightened recognition among students by way of active measures to increase the area's activity in the form of seminars, student events, job fairs, and the like.

First step to be taken by: universities and colleges relevant to the underwater technology area.

Addresses objectives:
2020:4,5,6,8,9,10,11,15,18,19,
20,25,26 + 2030:1,2,3,4,5,6,7,8,9,11,12,13,14

9 STANDARDIZATION

We propose that: a working group for standardisation is created, with the primary task of establishing standards for autonomous and controlled underwater vehicles. The working group will be involved in international activities, which take place within the framework of for example, EDA (SARUMS – Safety and Regulations for European Unmanned Maritime Systems) and NIAG (SG202). The work group should also work for open standards for oceanographic surveying.

First step to be taken by: the proposed partnership forum for underwater innovation.

Addresses objectives: 2020:15,21,23 + 2030:2,3,10,12

10 REVIEW OF LEGISLATION

We propose that: the forum will review existing laws that regulate the underwater technology sector to remove obstacles that creates hinders for a successful implementation of innovations. The focus of the review should be on legislation, international competition and intellectual property rights.

The presence of the forum in the role as national consultant ensures that necessary international feedback from the marketing side is transferred to the legislative process.

First step to be taken by: the proposed partnership forum for underwater innovation starts the process by contacting the Ministry of Defence, Swedish Maritime Administration, Ministry of Trade & Commerce, Ministry of Education and Ministry of Environment & Energy in partnership.

Addresses objectives: 2020:6,13,21,22 + 2030:2,3,7,8,10,12

11 CERTIFICATION

We propose that: a Swedish notified body is established that can certify technologies for use in the underwater technology sector, to minimize time and risk when forced to undertake certification abroad.

First step to be taken by: the proposed partnership forum for underwater innovation.

Addresses objectives: 2020:23,25 + 2030:2,3,10

12 MARITIME STRATEGY

We propose that: the underwater technology sector actively participates in further work with the national maritime strategy. The first activation will be participation in spring 2016.

First step to be taken by: the proposed partnership forum for underwater innovation.

Addresses objectives: 2020:8,9,20,24,26,27 + 2030:2,3,6,11,12,14

Strategic innovation agendas to cooperate with

”VERTICAL" SECTORS

In the forthcoming work of NRIA-U the following activities will be carried out: implementation and monitoring of the recommended activities, updating of the strategy and enter into relevant partnerships with other strategic innovation agendas. This will be done to secure synergies and create the best conditions for effectiveness in particular within the underwater technology innovation area and in general within the Swedish innovations system.

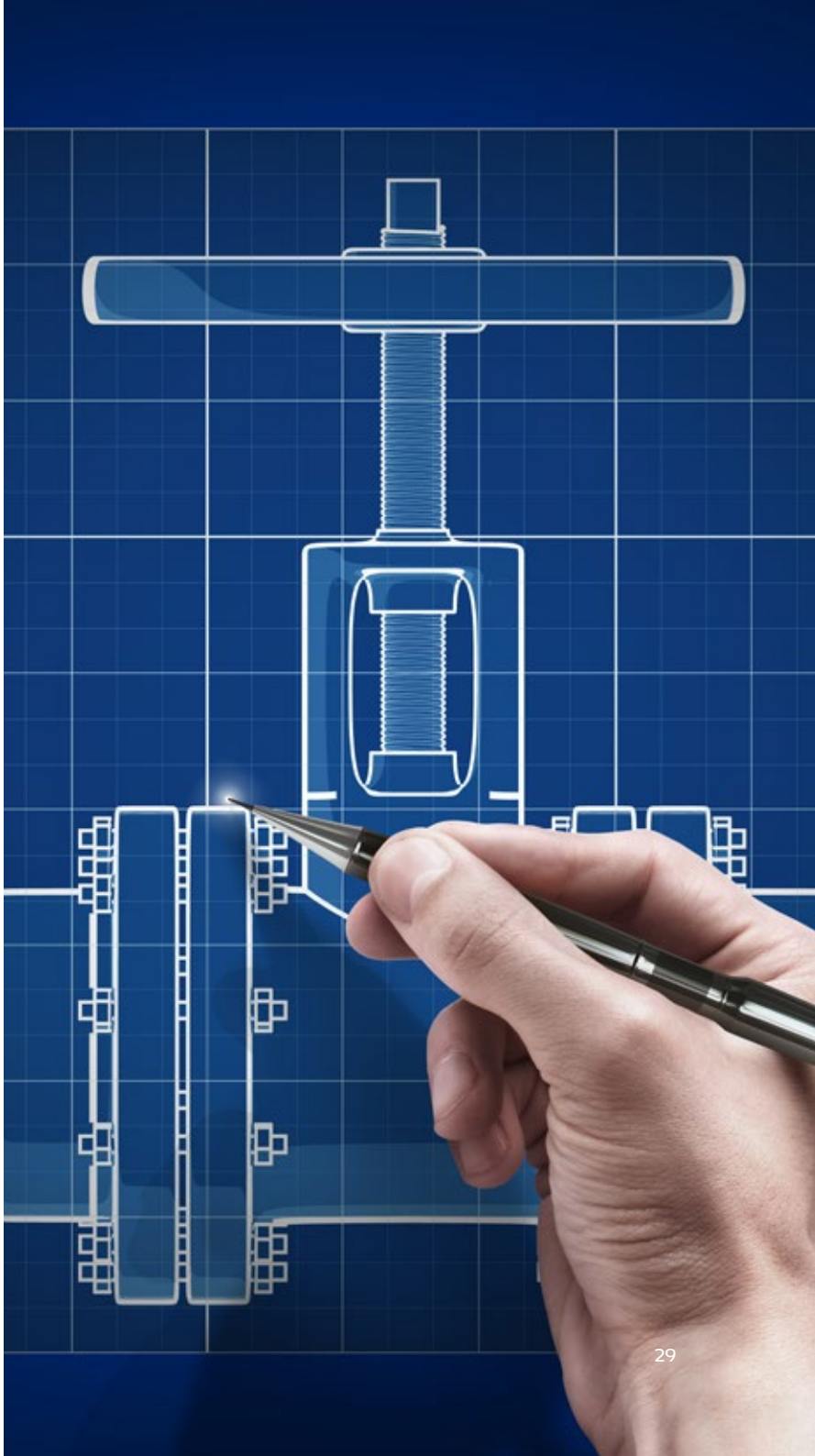
Some of innovation areas can be considered to be closely related and, similar to the underwater sector, structured “vertically” that is from the initial idea to providing an end-user market with products and services. We therefore see a potential in synchronizing our activities and our innovation with the following agendas:

- 2012-01810 **NRIA Flyg**
- 2012-01914 **Blå energi**
- 2012-01935 **Svensk maritim forsknings- och innovationsagenda**
- 2013-05237 **Marin elproduktion**
- P40420-1 **Vindenergi till havs**

”HORIZONTAL" SECTORS

There are also a variety of innovation sectors, which are ”horizontal” enablers for a large number of the vertical innovation sectors, including the underwater sector. We therefore see a potential to approach the following innovation agendas:

- 2012-01836 **A Swedish Strategic Research and Innovation Agenda for Software Development**
- 2012-01838 **Lättvikt lyfter svensk konkurrenskraft**
- 2012-01858 **Made in Sweden (produktion)**
- 2012-01900 **Big Data Analytics**
- 2012-01941 **Agenda för nationell samling kring metalliska material**
- 2012-01942 **Strategisk forsknings- och innovationsagenda Säkerhet**
- 2012-01943 **Innovation enabled by information and communication technologies**
- 2012-01945 **Nationell agenda Internet of things**
- 2012-01948 **Resurssmart materialanvändning**
- 2012-01951 **Modeller och systemsimulering**
- 2012-01972 **Life cycle based innovation**
- 2013-00638 **Trådlös kommunikation**
- 2013-02674 **Digital Innovation & Growth**
- 2013-05211 **GAME**
- 2013-05214 **Agenda Visuella Effekter**
- 2013-05220 **InnovAT – Agenda för Innovative Advanced Tooling**
- 2013-05224 **Additiv tillverkning och 3D-printing**
- 2013-05236 **Automatiserade transportsystem**



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