TNO Defence, Security and Safety

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TNO report

TNO-DV 2006 A455

Unmanned surface and underwater vehicles

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Onbemande op- en onderwatersystemen

Probleemstelling

Een van de (internationale) ontwikkelingen die consequenties kunnen hebben voor het opereren van de Koninklijke Marine (KM) is de introductie van onbemande systemen. De KM dient op termijn dan ook over voldoende kennis te beschikken om op gegronde redenen beslissingen te kunnen nemen met betrekking tot aanschaf en inzet van dergelijke systemen. In een eerdere studie is reeds gekeken naar alle typen onbemande systemen, inclusief onbemande vliegende systemen. De onderzoeksvraag van dit project luidt: 'Welke Defensie-capaciteiten kunnen met onbemande op- en onderwatersystemen worden uitgevoerd?'

Beschrijving van de werkzaamheden

Binnen dit project zijn huidige en toekomstige onbemande op- en onderwatersystemen geïnventariseerd en onderverdeeld in drie categorieën: location (underwater, semi-submersible, surface), control (remotely operated, autonomous) en function (reconnaissance, combat, rescue). Vervolgens is gepoogd de geïnventariseerde systemen te projecteren op de lijst van Defensiecapaciteiten uit het Defensie-rapport 'Lijst van Defensietaken en -capaciteiten versie finaal oktober 2004'. Dit bleek niet direct mogelijk, omdat de Defensiecapaciteiten voor deze studie niet gedetailleerd genoeg zijn uitgewerkt. Daarom zijn deze capaciteiten verder opgesplitst in 'subcapaciteiten', zodat vervolgens kon worden gekeken naar de geschiktheid van de geïnventariseerde systemen voor die subcapaciteiten. Aldus werd een tabel gegenereerd met capaciteiten en subcapaciteiten versus onbemande systemen (een X in een cel betekent: systeem i is geschikt om subcapaciteit j te vervullen).

Resultaten en conclusies

- Van de geïnventariseerde onbemande op- en onderwatersystemen zijn de meeste een Autonomous Underwater Vehicle (AUV) dat als hoofdtaak reconnaissance heeft.
- Een onbemand systeem dat als hoofdtaak rescue heeft, opereert onder water en wordt van afstand bediend.
- Een onbemand systeem dat als hoofdtaak combat heeft, opereert aan de oppervlakte in geval van active combat en onder water in geval van passive combat.

In het algemeen zijn onbemande onder-watersystemen zeer geschikt voor het uitvoeren van delen van de volgende Defensiecapaciteiten (DC's):

- Harbour defence (DC 57) against divers and Improvised Explosive Devices (IEDs)
- Maritime Mine Counter Measures capability (DC 65)
- Hydrographics (DC 69)

In het algemeen zijn onbemande semi-onderwatersystemen zeer geschikt voor het uitvoeren van delen van de volgende DC's:

- Harbour defence (DC 57) against divers
- Maritime Mine Counter Measures capability (DC 65)

In het algemeen zijn onbemande oppervlaktesystemen zeer geschikt voor het uitvoeren van delen van de volgende DC's:

- Anti Surface Warfare (ASuW) (DC 23)
- Border patrol (DC 54) above water
- Harbour defence (DC 57) against above water objects
- Coast guard (DC 62)
- Naval Co-operation (DC 74)
- Search And Rescue (SAR) (DC 84) above water
- Sea surveillance (DC 85)

Toepasbaarheid

Het rapport is een nuttig document voor fabrikanten, omdat het laat zien waar onbemande systemen op dit moment nog tekort schieten. Daarnaast is het document direct bruikbaar voor de afdeling DOBBP van Defensie voor het maken van afwegingen bij de verwerving van onbemande systemen voor de Krijgsmacht.

PROGRAMMA	PROJECT
Programmabegeleider KLTZ H.R. Lodder DS/DOBBP/Operationeel Beleid/ Toekomstverkenning	Projectbegeleider KLTZ H.R. Lodder DS/DOBBP/Operationeel Beleid/ Toekomstverkenning
Programmaleider drs. M. van den Brink TNO Defensie en Veiligheid	Projectleider ir. H.J. Fitski TNO Defensie en Veiligheid
Programmatitel Sea Basing	Projecttitel Onbemande Systemen
Programmanummer V508	Projectnummer 015.35069
Programmaplanning Start 1 december 2005 Gereed 31 december 2008	Projectplanning Start 1 juni 2005 Gereed 31 december 2006
Frequentie van overleg Met de programma/projectbegeleider werd meerdere malen gesproken over de invulling en de voortgang van het onderzoek.	Projectteam drs. R.H. Bremer ir. P.L.H. Cleophas ir. H.J. Fitski ir. D. Keus drs. J.A. Wilschut

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Rubricering rapport
Ongerubriceerd

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Abbreviations

ADCP	Acoustic Doppler Current Profiler
ADV	Acoustic Doppler Velocimeter
AHRS	Attitude and Heading Reference System
AINS	Aided Inertial Navigation System
AIS	Automatic Identification System
AMPS	Autonomous Mobile Periscope System
AOSN	Autonomous Oceanographic Sampling System
ARCS	Autonomous Remotely Controlled Submersible
ASDS	Advanced SEAL Delivery System
ASH	Autonomous Search and Hydrographic Vehicle
ASSV	Autonomous Semi-Submersible Vehicle
ASV	Autonomous Surface Vehicle
ASW	Anti Submarine Warfare
ASuW	Anti Surface Warfare
AUSI	Autonomous Undersea Systems Institute
AUSS	Advanced Unmanned Search System
AUV	Autonomous Underwater Vehicle
AV	Autonomous Vehicle
BASIL	Bases Autopropulsées pseudo-Stationnaires en réseau Interconnecté de Localisation
BPAUV	Battle space Preparation Autonomous Underwater Vehicle
CCD	Charge Coupled Device
COMINT	Communications Intelligence
COTS	Commercial Off-The-Shelf
CSS	Coastal Systems Station
CTD	Conductivity Temperature Depth
CTFM	Continuous Transmission Frequency Modulated
DC	Defence Capabilities
DOLPHIN	Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation
DON	Department of the Navy
DVL	Digital Video Log
ECM	Electronic Countermeasures
EDO	Type of doppler sonar
ELINT	Electronic Intelligence
EM	Electro Magnetic
ESM	Electronic Support Measures
EMATT	Expendable Mobile ASW Training Target
EO	Electro-Optical
EOD	Explosive Ordnance Disposal
EODRWP	Explosion Ordnance Disposal Robotic Work Package
EW	Electronic Warfare
FDS3	Forward Deployed Side Scan Sonar
FLASH	Folding Light Acoustic System for Helicopters
FLS	Forward Looking Sonar
FOMC	Fiber Optic Microcable
GPS	Global Positioning System
ICES	International Council for the Exploration of the Sea

IDEF	International Defence Industry Fair
IED	Improvised Explosive Device
IFF	Identification Friend or Foe
IMINT	Imagery Intelligence
INS	Integrated Navigation System
INTEL	Intelligence
IR	Infra Red
IRST	Infra Red Search and Track
ISE	International Submarine Engineering
ISR	Intelligence Surveillance and Reconnaissance
LED	Light Emitting Diode
LIC	Low Intensity Conflicts
MCM	Mine Counter Measure
MCMV	Mine Counter Measure Vessel
MIRIS	Mine Reacquisition and Identification Sonar
MMCM	Maritime Mine Counter Measures
MRS	Mine Reconnaissance System
MRU	Motion Response Unit
MW	Mine Warfare
NAVSEA	Naval Sea Systems Command
NLW	Non-Lethal Weapons
NUWC	Naval Undersea Warfare Center
NiCd	Nickel Cadmium
OBS	Optical Backscatter Sensor
ONR	Office of Naval Research
OST	Office of Special Technology
OTH	Over The Horizon
PAP	Poisson Auto Propulsé
PAR	Photo-synthetically Active Radiation
PMRF	Pacific Missile Range Facility
PPM	Parts Per Million
R&D	Research & Development
RD	RDI Acoustic Doppler
RDI	RD Instruments
REA	Rapid Environmental Assessment
REMUS	Remote Environmental Monitoring Unit System
RF	Radio Frequencies
RHIB	Rigid Hull Inflatable Boat
RMS	Remote Mine hunting System
RNoN	Royal Norwegian Navy
ROSSV	Remotely Operated Semi-Submersible Vehicle
ROSV	Remotely Operated Surface Vehicle
ROUV	Remotely Operated Underwater Vehicle
ROV	Remotely Operated Vehicle
SAHRV	Semi-Autonomous Hydrographic Reconnaissance Vehicle
SAM	System is a unique unmanned mine
SAR	Search And Rescue
SAS	Semi-Autonomous Systems
SASS	Survey Autonomous Semi-Submersible
SAUV	Solar powered Autonomous Underwater Vehicle
SEAL	Sea-Air-Land

SILOS	Side Looking Sonar
SIT	Silicon-Intensified Target
SLS	Side Looking Sonar
SPVDS	Self Propelled Variable Depth Sonar
SSC	Simulation Sweeping Craft
SSUS	Small-Size Unmanned Submersible
SUBMATT	Submarine Mobile Acoustic Training Target
SubROV	Submarine ROV
SUS	Small Unmanned Submersible
TIV	Tunnel Inspection Vehicle
TNO	Netherlands Organisation for Applied Scientific Research
TRL	Technology Readiness Level
TSM	Target Simulation Mode
TUS	Thales Underwater Systems
TV	Television
TWA	Time Weighted Average
UAV	Unmanned Air Vehicle
UCSSV	Unmanned Combat Semi-Submersible Vehicle
UCSV	Unmanned Combat Surface Vehicle
UCUV	Unmanned Combat Unmanned Vehicle
UCV	Unmanned Combat Vehicle
UDT	Underwater Defence Technology
UGV	Inmanned Ground Vehicle
UK	United Kingdom
UMV	Unmanned Vehicle
URSSV	Unmanned Rescue Semi-Submersible Vehicle
URSV	Unmanned Rescue Surface Vehicle
URUV	Unmanned Rescue Underwater Vehicle
URV	Unmanned Rescue Vehicle
URecSSV	Unmanned Reconnaissance Semi-Submersible Vehicle
URecSV	Unmanned Reconnaissance Surface Vehicle
URecUV	Unmanned Reconnaissance Underwater Vehicle
URecV	Unmanned Reconnaissance Vehicle
US	USA Status
USSOCOM	United States Special Operations Command
USSV	Unmanned Semi-Submersible Vehicle
USV	Unmanned Surface Vehicle
	Unmanned Space Vehicle
UUV	Unmanned Underwater Vehicle
	Unmanned Undersea Vehicle
UV	Unmanned Vehicle
VSW	Very Shallow Water

1 Introduction

The introduction of Unmanned Vehicles (UVs) may have serious consequences for naval operations. Therefore, in the future the Royal Netherlands Navy needs to have sufficient knowledge to be able to make sound decisions with respect to procurement and employment of such vehicles. In [1] research had already been carried out into all types of unmanned vehicles, inlcuding unmanned aerial vehicles. In this project it is examined which defence capabilities can be carried out with unmanned surface and underwater vehicles. This report can be considered a deepening of insight and an update of [1].

This research on UVs is staged as follows.

1 To formulate a list of definitions and abbreviations concerning Uvs, and to investigate the hierarchical context among these types of vehicles (for instance Autonomous Underwater Vehicles (AUVs) versus Small Unmanned Submersibles (SUSs)).
2 To make an inventory of current and future UVs.
3 To project the listed UVs on the task and capability list of the Royal Netherlands Navy.
4 To make an inventory of the employment possibilities of current and future UVs regarding the task and capability list of the Royal Netherlands Navy.
5 To formulate the employment possibilities of different types of UVs.

1.1 Reading instructions

This document is organized as follows. Chapter 2 explains the hierarchical context of different types of UVs based on three categories: location, control and function.
This chapter also explains the technology readiness levels in this document to indicate whether the UV is already in use, is a prototype or is just an idea. In Chapters 3, 4 and 5 we supply an inventory of UVs based on a literature study as well as an internet survey. In Chapter 6 we present the task and capability list of the Royal Netherlands Navy and further develop the capabilities into subcapabilities. In Chapter 7 the inventory of UVs is projected on the subcapability list. In Chapter 8 we summarize the inventory from Chapters 3, 4 and 5, briefly discuss the advantages and disadvantages of UVs, and draw some conclusions.

2 Research on the context of different types of UVs

2.1 Definition of UVs

In this research we developed three statements to define UVs and to rule out other systems.

1 *Able to move*
A UV has to be able to forward itself. For this purpose self moving sensors are taken into account, whereas dropped, static buoys are not considered UVs.

2 *Not meant to blow up*
Weapons (such as torpedoes) that are meant to destroy an object/enemy by destroying themselves, are not considered UVs is this study.
For instance: a Poisson Auto Propulsé (PAP) is considered a UV because it does not destroy itself (it drops an explosive and returns to the ship), whereas the Seafox mine-disposal system is not considered a UV but a weapon, because it destroys itself in order to destroy a mine.

3 *No pilot on board*
A UV does not have a pilot on board. However, transport of people is possible, so an 'unmanned taxi' is considered a UV.

Note that reusability is not a requirement of UVs. There are UVs that do not destroy themselves but still are meant for single use only. An example of such a system is the Flying plug (see Section 3.2.7).

2.2 Categories in which UVs can be subdivided

In the opinion of the project team, UVs can be categorised in three different ways: by their location, the way they are controlled or their function. In this study the following categories have been included.

- Location: surface, semi-submersible or underwater.
- Control: autonomous or remotely operated.
- Function: combat, reconnaissance or rescue.

In the category location a distinction is made between three types of UVs: Unmanned Underwater Vehicles (UUVs), Unmanned Semi-Submersible Vehicles (USSVs) and Unmanned Surface Vehicles (USVs). Note that a semi-submersible is never entirely underwater.

The second category is control and this is about to what extent a UV is remotely operated or autonomous. Therefore we have Remotely Operated Vehicles (ROVs) and Autonomous Vehicles (AVs). Note that the subset ROV includes all UVs that are untetheredly operated as well as the ones that are cable operated. Furthermore, autonomous means the AV cannot be adjusted or controlled from outside the vehicle. Either the vehicles follows a set of way points or it takes its decisions on its own.

Finally a distinction is made between the functions a UV has. In this document we defined the functions of the UV as follows: Unmanned Reconnaissance Vehicle (URecV), Unmanned Combat Vehicle (UCV) and Unmanned Rescue Vehicle (URV).

As defined, combat is part of the category function. With combat we cover active combat as well as passive combat. In active combat a UV is able to participate in a task force. Also target acquisition and target designation is seen as part of active combat. In a role of passive combat a UV is the target to be fired at and is thus a training target for other platforms. In Anti Submarine Warfare (ASW) the UV has to be traced by ASW platforms.

In the next section we will describe the context in which the three categories are defined.

2.3 The relationship between the categories location, control and function for UVs

In the previous section we described the three separate categories by which a UV can be defined. In this chapter we will describe what different types of UVs have been defined using these categories simultaneously. Therefore we put the following categories together defining new types of UVs:
- location and control;
- location and function.

2.3.1 Location and control

Firstly we put location and control together to describe UVs. This is defined in the following table and figure. Note that some abbreviations may not be generally accepted but have been developed for the purpose of this research. However, in developing these abbreviations, we tried to use widely accepted terms as much as possible.

Table 1 Location in relation with control.

	ROV (Remotely Operated)	AV (Autonomous)
USV	ROSV	ASV
UUV	ROUV	AUV
USSV	ROSSV	ASSV

The abbreviations stand for the following:.

ROSV: Remotely Operated Surface Vehicle
ROUV: Remotely Operated Underwater Vehicle
ROSSV: Remotely Operated Semi-Submersible Vehicle
ASV: Autonomous Surface Vehicle
AUV: Autonomous Underwater Vehicle
ASSV: Autonomous Semi-Submersible Vehicle

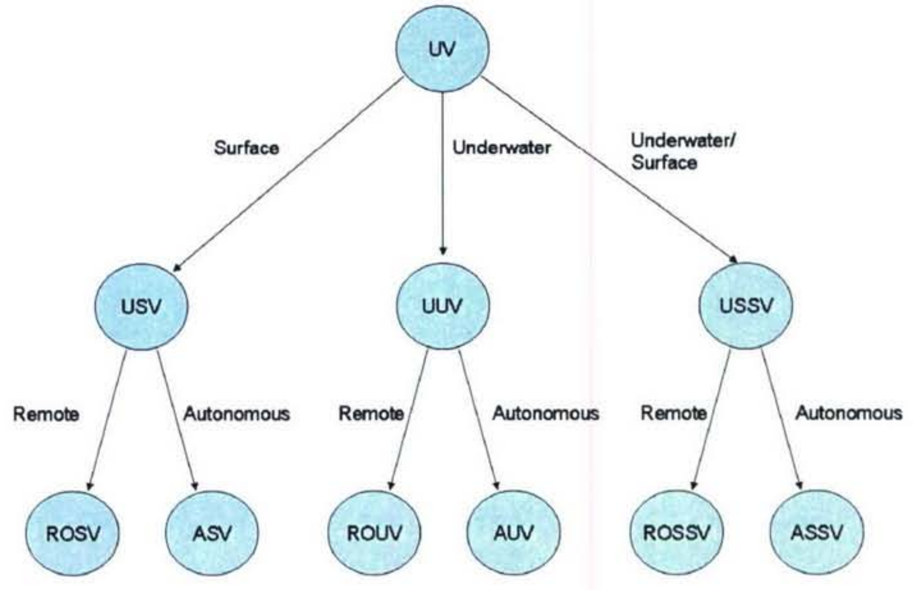


Figure 1 Using location and control to describe UVs.

For completeness we defined the figure again the other way around, see the following figure.

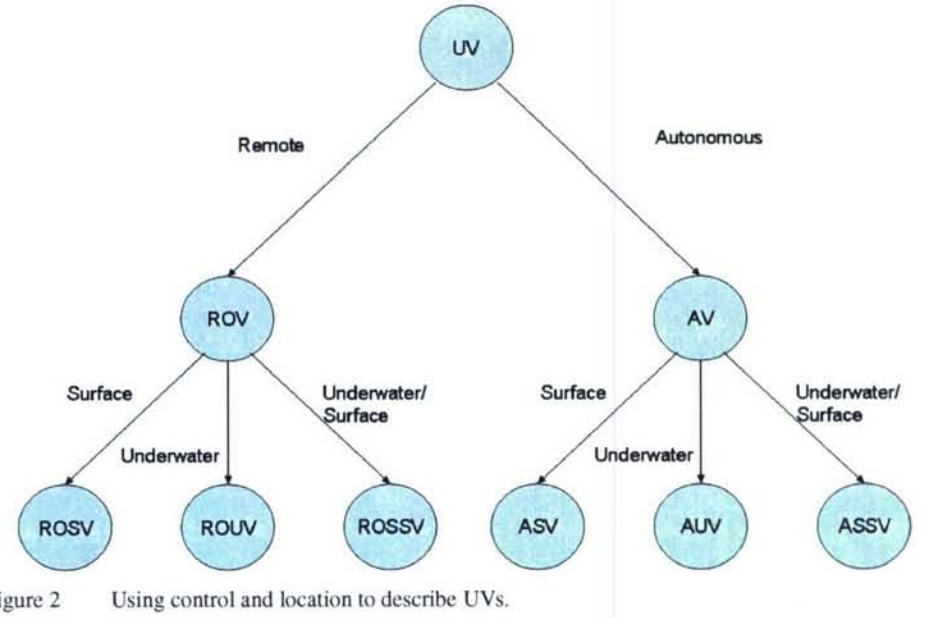


Figure 2 Using control and location to describe UVs.

2.3.2 *Location and function*

Accordingly, we can use location and function to further distinguish between the different types of systems. This is done similarly as in the previous section.

Table 2 Location in relation with function.

	URecV (Reconnaissance)	UCV (Combat)	URV (Rescue)
USV	UrecSV	UCSV	URSV
UUV	UrecUV	UCUV	URUV
USSV	URecSSV	UCSSV	URSSV

The abbreviations stand for the following.

URecSV: Unmanned Reconnaissance Surface Vehicle
URecUV: Unmanned Reconnaissance Underwater Vehicle
URecSSV: Unmanned Reconnaissance Semi-Submersible Vehicle
UCSV: Unmanned Combat Surface Vehicle
UCUV: Unmanned Combat Unmanned Vehicle
UCSSV: Unmanned Combat Semi-Submersible Vehicle
URSV: Unmanned Rescue Surface Vehicle
URUV: Unmanned Rescue Underwater Vehicle
URSSV: Unmanned Rescue Semi-Submersible Vehicle

Note that we added Unmanned in the beginning of these abbreviations. This has been done to be in accordance with commonly accepted abbreviations for UVs.

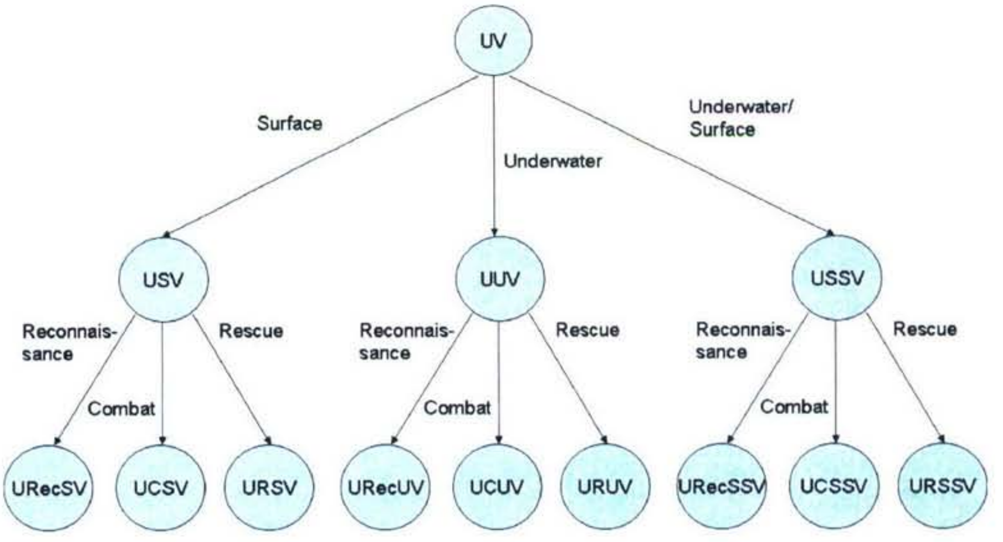


Figure 3 Using location and function to describe UVs.

For completeness we defined the figure again the other way around, see the following figure.

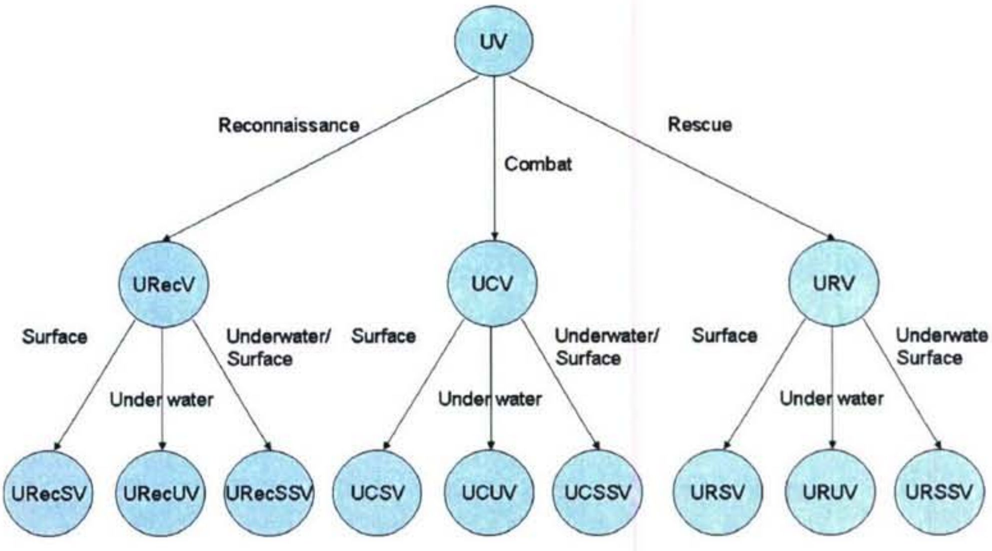


Figure 4 Using function and location to describe UVs.

Note that we used two times two categories to describe the different types of unmanned systems. Because of this an unmanned system always belongs to a branch of one of the two trees defined in the previous two sections. Suppose we have a USV that is remotely operated and has as function reconnaissance, then this USV can be characterized as Remotely Operated Surface Vehicle (ROSV) as well as Unmanned Reconnaissance Surface Vehicle (URecSV).

In the next section we will explain how we used technology readiness levels to indicate the current development stage of the UV. In Chapters 3, 4 and 5 we supply a survey of different UVs. The three categories defined in this chapter form the thread of this inventory. In Chapter 7 we merge all systems in a matrix regarding the defence capabilities described in Chapter 6.

2.4 Technology Readiness Levels

One of the criteria which we will discuss on UVs is to what extent a given system is in operational use. An international accepted criterion to do this is to indicate the Technology Readiness Level (TRL) of a UV. Technology Readiness Levels (TRL) are a sequence of carefully-defined levels of technology maturity, intended to help communicate the developmental status and risk of emerging technologies.
Of course, the selection of the specific TRL number for a particular technology is often a matter of opinion, but properly used, TRLs should replace vague and self-serving statements like ‘our concept is low risk’. The TRL scheme has been used by NASA and is codified in the military acquisition document DoD 5000.2R, Appendix 6.
In the following of this section we briefly summarize the different levels of technology.

1 *Basic principles observed and reported*
Lowest level of technology readiness. Scientific research begins with to be translated into applied research and development. Example might include paper studies of a technology's basic properties.
2 *Technology concept and/or application formulated*
Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3 *Analytical and experimental critical function and/or characteristic*
Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4 *Component and/or breadboard validation in laboratory environment*
Basic technological components are integrated to establish that the pieces will work together. This is relatively 'low fidelity'compared to the eventual system. Examples include integration of 'ad hoc' hardware in a laboratory.
5 *Component and/or breadboard validation in relevant environment*
Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include 'high fidelity' laboratory integration of components.
6 *System/subsystem model or prototype demonstration in a relevant environment*
Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7 *System prototype demonstration in an operational environment*
Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft.
8 *Actual system completed and 'flight qualified' through test and demonstration*
Technology has been proven to work in its final form and under expected conditions.
In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9 *Actual system 'flight proven' through successful mission operations*
Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last 'bug fixing'aspects of true system development. Examples include using the system under operational mission conditions.

In this report we decided to use TRLs on a less detailed level. This is done because it is quite hard to recover the exact TRL for a given system. It would rather be pretended accuracy to set a detailed TRL for a system. Therefore we developed the statement idea, prototype and in use which we connected as follows to the technology levels.
1 Idea: level 1 up to level 5.
2 Prototype: level 6 up to level 8.
3 In use: level 9.

3 Inventory of different types of UUVs

In this part we actually provide the inventory of systems which we found in literature or in an internet survey. In order to do this, we subdivided all discovered UVs according to the three categories defined in Chapter 2. Resuming the categories we have:
- location (Underwater, Semi-Submersible and Surface);
- control (Autonomous and Remotely Operated);
- function (Combat, Reconnaissance and Rescue).

We also used these categories to define our sections and we therefore have 3 times 3 times 2 is 18 subcategories. In Chapter 3 we start with the inventory of UUVs, then we continue with USSVs in Chapter 4 and finally we make an inventory of USVs in Chapter 5.

3.1 Underwater – Autonomous – Combat

3.1.1 AMPS

AMPS: Autonomous Mobile Periscope System.

Picture:
No picture found.

Source:
http://www.globalsecurity.org/intell/systems/amps.htm
http://underwater.iis.u-tokyo.ac.jp/ut98/abst5.html

Description:
The AMPS will represent the above water portion of a submarine running at periscope depth. A simulated attack periscope and mast will be mounted to a free running, underwater vehicle. The vehicle will position and propel the periscope over a prescribed path and will have the capability to submerge the periscope at various intervals.
The vehicle path can be radio controlled or preprogrammed. Other AMPS requirements include the ability to operate for five hours without battery recharge and be launched and recovered by PMRF's 85' range support boars without a crane.

Development:
Pacific Missile Range Facility (PMRF) and the Carderock Dimensions and classification of the Naval Surface Warfare Center (CDNSWC).

Status:
Prototype.

Dimensions:
Length 26.5 feet.
Diameter 2 feet.
Weight 3,600 pounds.

Sensors:
Target acoustic system, which enables AMPS to broadcast sounds associated with an operating submarine, improving the realism of the training target presented to ASW units.

Endurance:
Five hours.

Tasks:
Realistic target for training of ASW units, above water as well as underwater.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Combat.

Table 3 Classification of AMPS.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-function	UCUV	Unmanned Combat Underwater Vehicle

Expected specific advantage:
AMPS meets the requirement for an inexpensive readily available periscope detection target.

3.1.2 *EMATT / SUBMATT*

EMATT: Expendable Mobile ASW Training Target.
SUBMATT: Submarine Mobile Acoustic Training Target.

Picture:

Source:
http://www.sippican.com/contentmgr/showdetails.php/id/345
http://www.sippican.com/contentmgr/showdetails.php/id/378

Description:
The MK 39 Expendable Mobile Anti Submarine Warfare Training Target, or EMATT, was designed through the eyes of a submariner. The result is a small, dynamic submarine-like target equipped with acoustic and non-acoustic signatures.
Lockheed Martin Sippican has produced over 14,000 EMATTs for the U.S. Navy and other allied navies around the world. The EMATT can be deployed from aircraft or surface ships to enhance fleet readiness for anti submarine warfare. Lockheed Martin Sippican produces EMATTs for the US and other foreign navies. EMATT follows a preprogrammed course, depth, speed, time and passive tonal changes. The SUBMATT training target is a submarine launched version of the EMATT.

Development:
Lockheed Martin Sippican, Marion, Massachusetts, VS (by order of NUWC).

Status:
In use.

Dimensions:
Length 915mm.
Diameter 124mm.
Weight 10 kg.

Sensors:
Acoustic and non-acoustic signatures.

Endurance
Sulfur Dioxine battery: 5 PPM TWA 8 hour.
Acetonitrille battery: 40 PPM TWA 8 hour.

Tasks:
Realistic target for the training of ASW units.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Combat.

Table 4 Classification of EMATT/SUBMATT.

Location-control	AUV	Autonomous Underwater Vehicle
Location-function	UCUV	Unmanned Combat Underwater Vehicle

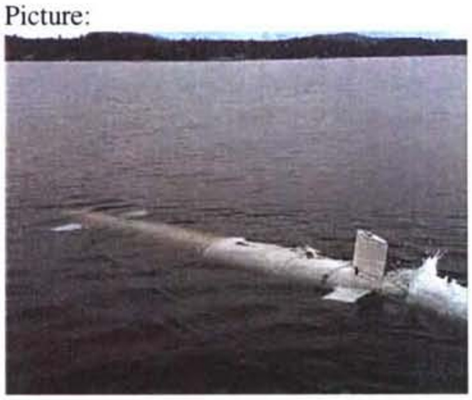
Expected specific advantage:
EMATT is widely used, Lockheed Martin Sippican has produced over 14,000 EMATTs for the US and foreign navies.

3.2 Underwater – Autonomous – Reconnaissance

3.2.1 ARCS

ARCS: Autonomous Remotely Controlled Submersible.

Picture:



Source:
http://www.ise.bc.ca/arcs.html

Description:
The ARCS vehicle was developed by ISE Research Ltd as a platform for autonomous vehicle research. The vehicle has autonomous control, navigation, and guidance capability. Since 1987, the vehicle has been used for the development and demonstration of autonomous underwater vehicle technologies. This has included development of mission controllers, navigation systems, variable ballast and trimming concepts and advanced power sources. Users of the ARCS vehicle system include the Department of National Defence, Johns Hopkins Applied Physics Laboratory, Rockwell International and Fuel Cell Technologies. Over 800 dives have been conducted.

Development:
International Submarine Engineering (ISE) Ltd, Port Coquitlam, BC, Canada.

Status:
In use.

Users of the ARCS vehicle system include the Department of National Defence, Johns Hopkins Applied Physics Laboratory, Rockwell International and Fuel Cell Technologies. Over 800 dives have been conducted.

Dimensions:
Length: 6.4 m / 21 feet,
Diameter: 68.6 cm / 27 inches,
Displacement: 1360.8 kg / 3000 lb.

Sensors:
EDO 3050 Doppler sonar and ISE Mesotech 200 kHz obstacle avoidance sonar.

Endurance:

Speed:	4 knots; 5.5 knots (top).
Range:	36 km / 22.5 Nm with single NiCd battery.
	72 km / 45 Nm with double NiCd battery.
	235 km / 125 Nm with aluminum oxygen fuel cell.
Power:	One or two 10 kWh Nickel Cadmium batteries.
	100 kWh Aluminum Oxygen fuel cell.

Tasks:
Since 1987, the vehicle has been used for the development and demonstration of autonomous underwater vehicle technologies. This has included development of mission controllers, navigation systems, variable ballast and trimming concepts and advanced power sources. In 1997, a 100 kWh aluminum oxygen fuel cell was successfully tested on a 35 hour continuous run.

Classification:

Location:	Underwater.
Control:	Autonomous.
Function:	Reconnaissance.

Table 5 Classification of ARCS.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:

-

3.2.2 *AUSS*

AUSS: Advanced Unmanned Search System.

Picture:

Source:
http://www.fas.org/irp/program/collect/uust9.htm
http://www.nosc.mil/robots/undersea/auss/auss.html

Description:
The AUSS system is based on a radically different approach to the problem of deep search, one which totally eliminates the classic long cable. The heart of the system is a vehicle which is both unmanned and untethered yet provides human operators with nearly real-time data and control. Operators on the surface ship evaluate search images, status information, and navigation data, and direct the mission; but with no cable. Instead of miles of cable, AUSS uses an acoustic data link for communication between the vehicle and ship. The result is a supervisory controlled UUV, capable of both rapid search and precise inspection at depths as great as 20,000 feet.

The acoustic link transmits compressed search data to the surface at rates up to 4800 bits per second, and sends high level commands to the vehicle at 1200 bits per second. Joystick type control is not necessary because all critical control loops are closed on the vehicle. The operator tells the vehicle where to go and what to do, not how to do it. The vehicle's computers use Doppler sonar and a gyrocompass to perform onboard navigation. The vehicle can be commanded to go to a specific location and hover there, or to execute large search patterns without assistance.It autonomously performs each task until it is completed or until the operators interrupt with a new command.

Development:
Spawar Systems Center San Diego.

Status:
Prototype? Note that the Advanced Unmanned Search System was transferred to the Navy's Supervisor of Salvage and Diving in 1994.

Dimensions:
17 feet long, 31 inches in diameter, and weighs 2800 pounds.

Sensors:
Doppler sonar and gyrocompass to perform onboard navigation.
The two types of general purpose underwater search sensors employed are sonar and optical.

- Side Looking Sonar (SLS) with a maximum 2000 foot range scale, or 4000 foot swath.
- Scanning Forward Looking Sonar (FLS) for closing in on sonar targets.
- Charge Coupled Device (CCD) electronic still camera (optical sensor) to quickly identify 'false targets'(which on sonar resemble that which is sought), and to perform detailed inspections of items of genuine interest.

Endurance:
The endurance of the AUSS silver-zinc batteries is ten hours, at its maximum speed of five knots.

Tasks:
Locate and inspect (classify, identify) objects on the ocean bottom over wide areas (1 sq-nm/hr).

Classification:
Location: Underwater.
Control: Autonomous (supervisory controlled, untethered).
Function: Reconnaissance.

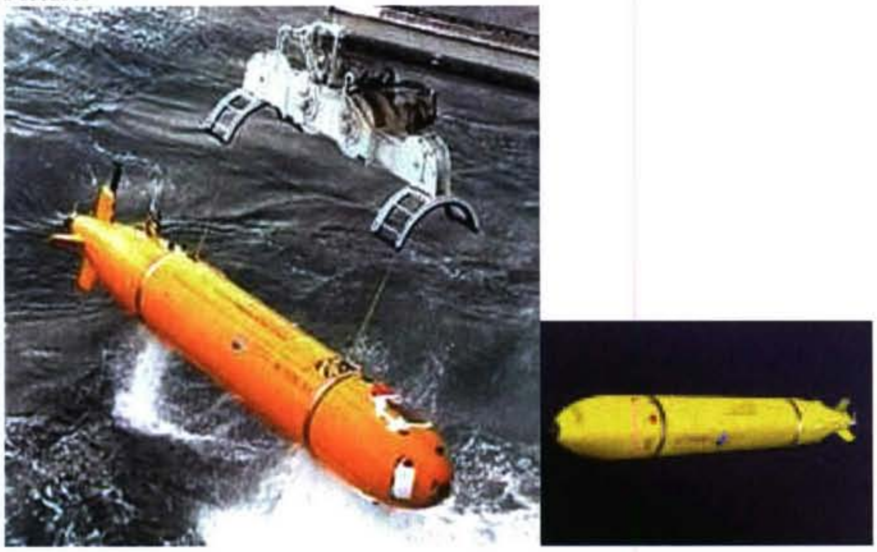
Table 6 Classification of AUSS

Location-control	AUV	Autonomous Underwater Vehicle
Location-function	URecUV	Unmanned Reconnaissance UnderwaterVehicle

Expected specific advantage:
Untetheredly operated and data transmission by an acoustic data link.

3.2.3 *Autosub-1*

Picture:



Source:
http://www.soc.soton.ac.uk/OED/usl_index.php?page=as

Description:
Autosub is a long range, deep diving, autonomous underwater vehicle (AUV). It can carry a wide variety of physical, biological and chemical sensors to provide scientists with the capability to monitor the oceans in ways not possible with conventional research ships. Autosub can collect physical, chemical, biological and geophysical data from the ocean surface to the seabed. The actual sensors and sampling devices carried on each mission can be tailored to fit different science needs.

AUVs such as Autosub can survey remote environments that are inaccessible to ROVs and other submersibles. Since 1996, Autosub has completed more than 200 deployments, demonstrating the capability for unescorted missions, routine launch and recovery in Force 6 conditions, sensor or data driven path determination and terrain following. The vehicle has been employed in projects ranging from herring stock assessment in the North Sea to mapping manganese distributions in a sea loch. Autosub has also successfully undertaken missions beneath sea ice in the marginal ice zone of the Weddell Sea.
Autosub measurements can include conductivity, temperature, transmissivity, fluorescence, photo-synthetically active radiation (PAR), current velocities, turbulence, ice draft, and water depth. Sub-bottom acoustic profiling can reveal structures of glacial origin in the seafloor sediments, while a water sampler can collect samples for geochemical and biological analyses. Swath bathymetry and side scan sonar can provide measurements of ice shelf, sea ice and ocean bottom relief at high resolution. Other instruments can also be accommodated on the vehicle.

Development:
National Oceanography Centre, Southampton, UK.

Status:
In use (for scientific purposes).

Dimensions:
Length 7 metres, 0.9 metres diameter.

Sensors:
Wide variety of physical, biological and chemical sensors to provide scientists with the capability to monitor the oceans.

- Seatex MRU 6 attitude sensor for magnetic heading, pitch and roll.
- Digiquartz 430 kT 700 bar pressure sensor for depth data.
- Simrad Mesotech 808 echo sounder with 300 metre range for altitude information and collision avoidance.
- Seabird SBE9 Conductivity, Temperature, Depth (CTD) sensor and Teledyne RD Instruments (RDI) Acoustic Doppler Current Profiler (ADCP).
- Fluorometer.
- Transmissometer.
- Oxygen sensor.
- In situ manganese sensor.
- Flow cytometer.
- 50 x 0.5 litre water sampler.
- Turbulence probe.
- Additional ADCPs.
- Upward-looking sonars.
- Sidescan sonars.
- Swath bathymetry.
- Digital cameras.

Endurance:
The Mn alkaline batery providing more than 500 km range or 6 days endurance in optimal conditions with low power demand.

Tasks:
Data collection, it has successfully undertaken missions beneath sea ice in the marginal ice zone of the Weddell Sea, water measurements.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 7 Classification of Autosub-1.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
It can carry a wide variety of physical, biological and chemical sensors to provide scientists with the capability to monitor the oceans in ways not possible with conventional research ships. It is employable in hard circumstances and high demanding operations in artic environments. Deepest Mission: 1003 m, Longest Mission: 262 km, 50 hrs.

3.2.4 *BPAUV*

BPAUV: Battle space Preparation Autonomous Underwater Vehicle.

Picture:

Source:
http://www.bluefinrobotics.com/bluefin_21bpauv.htm
http://www.auvsi.org/news/index.cfm
http://www.globalsecurity.org/intell/systems/bpauv.htm

Description:
As demonstrated in a series of Fleet Battle Experiments, the Bluefin-21 BPAUV covertly gathers accurate bathymetry and bottom classifications for use in the early stages of battle space preparation. It can operate in a wide range of weather conditions, day or night, without compromising data accuracy and can be deployed from vessels as small as 40 feet. On-deck turnaround is kept to less than 2 hours by Blue fin's unique battery modules, which can be swapped without opening a pressurized vessel.
A full load of fresh batteries can power the vehicle for 18 hours of survey at 3 kts, covering 150 m swathes in water depths up to 200 m. Reprogramming is swift and accurate, thanks to Blue fin's intuitive operator's software.

Development:
Bluefin Robotics, Cambridge, Massachusetts (by order of ONR).

Status:
Prototype/in use?

Dimensions:
Length: 130", Width: 21", Weight: 800 pounds (1,000 wet).

Sensors:
The Bluefin-21's high-performance and self-contained navigation system eliminates the need for acoustic beacons. The vehicle integrates AHRS and DVL data while submerged and periodically surfaces for GPS updates.
In its standard configuration the Bluefin-21 carries a high-performance 455 kHz sidescan sonar that provides a 10 cm resolution along track and a 7.5 cm resolution across track.

Endurance:
A full load of fresh batteries can power the vehicle for 18 hours of survey at 3 kts, covering 150 m swathes in water depths up to 200 m.

Tasks:
Autonomous bottom mapping/classification and target localization capabilities for MCM missions.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 8 Classification of BPAUV.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
The navigation of the BPAUV is highly accurate because of integration of AHRS and DVL data.

3.2.5 *Cetus II*

Picture:

Source:
http://web.nps.navy.mil/~cirpas/Projects/KB01%20Activity%20Summary.pdf
http://web.nps.navy.mil/~brutzman/Savage/Robots/UnmannedUnderwaterVehicles/CetusFlyerMarch2001.pdf
http://www.afcea.org/signal/articles/anmviewer.asp?a=529&z=58
http://www.didson.com/NEWS/REPORTS/ObjectIDAcousticLenses.pdf

Description:
Cetus II is a low cost UUV designed to locate, inspect, and where necessary, neutralise mines and mine-like objects in shallow waters (from 33 to 525 feet). Cetus II, which is about the size of a sea trunk, carries high-frequency sonar and low-light video imaging equipment to obtain high-quality images of underwater objects from more than 19 feet

away. The sensor data is logged onboard and downloaded when the vehicle is recovered. It is the smallest hover capable UUV and may be launched and recovered from small boats with minimal handling equipment. Equipped with high frequency imaging sonar and low light video imaging equipment, Cetus II searches for mines in a number of pre-determined search patterns, sensor data being logged on board the
54 in long, 28 in wide UUV, which can locate, detect, classify and identify mine-like objects in water depths from 22-525 ft.

Development:
Perry Technologies (Lockheed Martin), Sunnyvale, California, USA
NavSea, Explosive Ordnance Disposal Technology Dimensions and classification, USA.

Status:
Prototype.

Dimensions:
Length 54 in (1.37 m), Width 28 in (71 cm), Weight 120 lbs (54.5 kg) dry, 175 lbs (79.5 kg) wet.

Sensors:
Navigation means:
- Long Base Line;
- Differential GPS Doppler INS.

Sensor packages:
- Bottom Acoustical Imaging;
- Acoustic Doppler.

Major sensors are a high frequency (2 MHz) imaging sonar developed by UW / APL and low light video imaging.
With the Explosion Ordnance Disposal Robotic Work Package (EODRWP), Cetus II is being applied to the problems of search and evaluation of mines and other ordnance.

Endurance:
?

Tasks:
Cetus II has the mission to swim to a number of predetermined locations where mine-like objects have been detected. At each location, Cetus II must obtain additional information to identify the mine or determine that the object is not a mine. MIRIS (Mine Reacquisition and Identification Sonar) and a video camera are the primary sensors.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

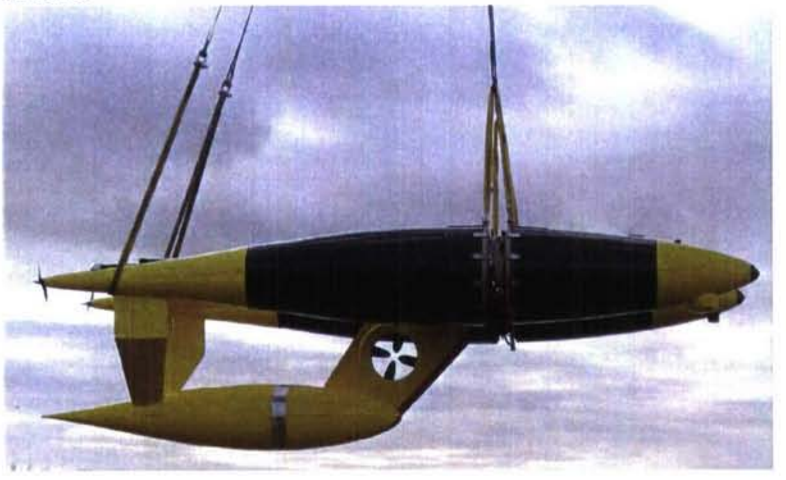
Table 9 Classification of Cetus II.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
The Cetus II is able to hover above targets. Furthermore, it is small and light so it can be deployed from relatively small vehicles.

3.2.6 *DeepC*

Picture:



Source:
http://www.deepc-auv.de/deepc/englisch/e_home.html
http://www.dnv.com/software/all/deepc/
http://www.hydrographicsociety.org/Articles/journal/2001/101-1.htm

Description:
The objective of the DeepC project is to develop a containerized AUV system whose underwater vehicle can be launched from a floating carrier platform, from land or from a helicopter. Once launched, it performs the preplanned mission fully autonomously and returns to the defined recovery point after completion of the mission.
After buying the Danish company Maridan, Altas Elektronik acquired sufficient AUV technology (the M600, now called SeaOtter Mk1). Therefore, development of DeepC was abandoned.

Development:
Atlas Elektronik, Bremen, Germany and partners.

Status:
Idea/prototype.

Dimensions:
Weight (in air): 2.4 tons.

Sensors:
Forward looking sonar.
Endurance:
Mission duration of 60 hours (at 4 kts).

Tasks:
Survey, data collection of oil and gas and telecommunication.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

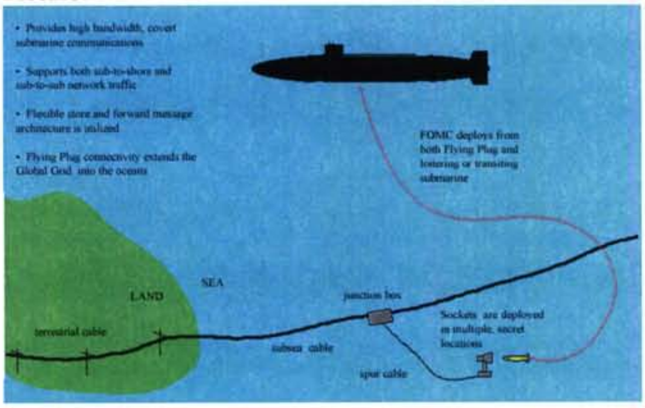
Table 10 Classification of DeepC.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
The fundamental feature of the intelligent DeepC behavior is the ability to successfully prevent a collision situation autonomously. The AUV should be able to avoid several objects that may be moving and return to the required path on the shortest or safest route, taking into account the dynamic properties of the AUV and the objects to be avoided, the environmental influences (currents, depth), the limited range of the sensors (e.g. the forward looking sonar in this case) as well as the range-dependent detection quality and resolution of the sensors in medium water.

3.2.7 *Flying plug*

Picture:



Source:
http://www.spawar.navy.mil/robots/undersea/plug/plug.html
http://www.globalsecurity.org/intell/systems/flying-plug.htm
http://www.nosc.mil/robots/pubs/subtech.pdf
http://www.nosc.mil/robots/undersea/plug/plug.html

Description:
The Flying Plug is a prototype underwater data connectivity device developed by SSC San Diego under the ONT Blue Sky Program and subsequently adopted by the ONR Surveillance Program. It is designed for deployment from submarines, aircraft and surface vessels.
Some years ago the U.S. Navy developed expendable fiber optic microcable (FOMC). FOMC is a tiny fiber optic cable, consisting of a single commercial optical fiber surrounded by a concentric strength-member of fiberglass-reinforced polymer, which can be manufactured inexpensively enough to be thrown away after each use.

The Flying Plug system consists of a potentially expendable underwater vehicle and a reusable underwater docking station called the Socket. In order to reduce recurring costs, the vehicle itself consists only of a minimal wet-end system which provides propulsion, homing sensors, electrical energy and data couplers. The vehicle is autonomously guided by signal processing and control computers located at its launch point by means of a deployed FOMC, and all signal processing and command/control associated with the Flying Plug is performed via its FOMC.

Development:
Spawar Systems Center San Diego.

Status:
Idea.

Dimensions:
Diameter 9 inches, 50 inches in length (it is sized so that, conceptually, it could be launched from the trash disposal unit of a nuclear submarine).

Sensors:
Homing sensors (to localise the Socket) and data couplers.

Endurance:
The propulsion battery provides adequate energy to deploy all the communications coil. Vehicle power is provided by rechargeable NiCad battery packs. At a speed of 3.5 knots a typical 1000 foot docking run requires only a few minutes of thruster operation.

Tasks:
Undetectable, high speed underwater communication.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Communication.

Table 11 Classification of Flying Plug.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
The Flying Plug enables communication with submarines which is important for Network Centric Warfare.

3.2.8 *Gavia AUV*

Picture:

Source:
http://www.gavia.is/products/index.html
http://www.gavia.is/news/index.html

Description:
The Gavia autonomous underwater vehicle (AUV) is a fully modular, small torpedo shaped vehicle capable of diving down to 2000 metres with long endurance underwater. Gavia is an extremely capable autonomous system in a small and easily deployable package that can be configured for a wide range of research, surveying or monitoring tasks.
On the 9th of september 2005, following an accident just outside Reykjavik, Gavia participated in a Search and Rescue mission by covering a 150,000 square meter search area in two hours, in search of the bodies of the two deceased. Using Side Scan Sonar images taken from the Gavia coupled with its highly accurate positioning system it was possible to more effectively employ the divers to limit their search areas to possible targets allowing for a much larger area to be searched in a shorter period of time.

Development:
Hafmynd - Gavia Ltd, Reykjavik, Iceland.

Status:
In use.

Dimensions:
Length: from 1.7 m, Diameter: 0.2 m, Weight: from 44 kg.

Sensors:
- Ssingle and dual frequency side-scan sonars.
- High definition digital cameras.
- Oceanographic CTD sensors.
- ADCP current profilers.
- Swath bathymetry sonar.

Endurance:
The Gavia can be operated with one or more battery modules depending on the endurance required for a particular mission. Battery modules are available for two different cell types: cost-efficient rechargeable Lion cells and single use Lithium cells that offer a greater endurance.

Tasks:
The Gavia is able to do tasks such as mine counter measures, survey, search and rescue operations (only the search part), coastal drug control and an application as a delivery vehicle.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 12 Classification of GAVIA AUV.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
Flexible (modular), small, light.

3.2.9 *Hugin 1000*

Picture:

Source:
http://www.km.kongsberg.com/ks/web/nokbg0240.nsf/allweb/268c1dfed8fa803fc1256cf00054b2a3?opendocument
http://www.mil.no/felles/ffi/hugin/start/program/hmrs/
http://www.mil.no/felles/ffi/hugin/start/program/HUGIN_MRS_pilot_system/
http://www.km.kongsberg.com/KS/WEB/NOKBG0240.nsf/AllWeb/B3F87A63D8E419E5C1256A68004E946C?OpenDocument

Description:
The Hugin 1000 Autonomous underwater vehicle is capable of performing high-speed surveys with excellent navigation and payload data quality down to a depth of 1000 meters. The vehicle can be operated in either operator supervised or full autonomous mode. The special hydrodynamic shape, optional launching system and overall principles of the previous Hugin 1 and 2 (operating in the North Sea since 1997) and the deepwater Hugin 3000 vehicles have been further developed into the Hugin 1000 design.
Three commercially operated Hugin vehicles have surveyed approximately 40,000 line kilometres to date; enough to circle Earth at equator. Compared to the commercial Hugin vehicles, Hugin 1000 has numerous enhancements to make it even better suited for military applications in the littoral: High quality autonomous navigation, full redundancy of most subsystems, improved mission programming flexibility, and an extended suite of communication systems. Two-way acoustic communication has been verified operationally out to more than 4 km range in very shallow water.
A full-capability system, called Hugin 1000-MR (MCM/REA), was ordered by Royal Norwegian Navy (RnoN) in June 2005. This system will feature a high resolution interferometric SAS as its primary sensor.

The autonomous underwater vehicle can be operated in either operator supervised ('acoustic tether') or autonomous mode. The Hugin AUVs are able to propel themselves, navigate, handle unforeseen circumstances, and achieve the mission objectives as set forth in a mission plan, without human intervention. The Hugin AUVs are equipped with acoustic communication links. This link increases the flexibility and robustness of the system, and facilitate various levels of remote control by a human operator. The operator is normally located on the same surface vessel that prepares, launches, recovers and services the AUV. While the vehicle is pre-programmed for its mission, and able to handle a large number of malfunctions and anomalies, the acoustic communications result in a higher level of confidence that the system works as programmed.

Development:
FFI, Kongsberg Maritime and the Royal Norwegian Navy, Norway.

Status:
Prototype.

Dimensions:
Length: 4 to 5 m (centre section can be built in different lengths).Maximum diameter: 0.75 m. Weight in air: approximately 650 kg.

Sensors:

- (Interferometric) Synthetic aperture sonar or side-scan sonar.
- Multibeam echo sounder.
- Sub-bottom profiler.
- CTD.
- Volume search sonar.

Endurance:
24 hours at 4 knots.

Tasks:
The Hugin 1000 vehicle is a key element in the Hugin Mine Reconnaissance Program. The main operations for Hugin Mine Reconnaissance System (MRS) are:

- High quality bathymetric mapping.
- Mine Counter Measure (MCM) route survey.
- Mine reconnaissance.
- Mine detection, classification and positioning.
- Overt and covert Rapid Environmental Assessment (REA).

Classification:
Location: Underwater.
Control: Autonomous (or Remotely Operated).
Function: Reconnaissance.

Table 13 Classification of Hugin 1000.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Control	ROV	Remotely Operated Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
- Very stable and low noise hydrodynamic platform for payload sensors.
- State of the art Aided Inertial Navigation System (AINS).
- Latest battery technology with up to 24 hours endurance at 4 knots.
- Typical payload sensors are synthetic aperture sonar or side-scan sonar, multibeam echo sounder, sub-bottom profiler, CTD and volume search sonar.

3.2.10 *Hugin 3000*

Picture:

Source:
http://www.km.kongsberg.com/KS/WEB/NOKBG0240.nsf/AllWeb/6DE7508561515DB5C1256E450036EE3B?OpenDocument
http://www.cctechnol.com/uploads/204_0.pdf

Description:
The Hugin 3000 AUV is an autonomous underwater sensor carrier taking high-resolution sensors down to where they belong: just above the seabed. The vehicle can be operated in either operator supervised or autonomous mode down to an operating depth of 3000 meters. High speed and long endurance makes this proven and groundbreaking technology extremely efficient. The special hydrodynamic shape, optional launching system and overall principles of the original Hugin 1 and 2 have been extended into the Hugin 3000 design. The additional capabilities of the Hugin 3000 include significantly longer battery endurance and the ability to carry several different types of survey sensors for synchronized and simultaneous operation.
The Hugin concept allows integration of alternative sensors for geophysical research and inspection purposes to be implemented, subject to customer demands.
The autonomous underwater vehicle can be operated in either operator supervised ('acoustic tether') or autonomous mode. The Hugin AUVs are able to propel themselves, navigate, handle unforeseen circumstances, and achieve the mission objectives as set forth in a mission plan, without human intervention.
The Hugin AUVs are equipped with acoustic communication links. This link increases the flexibility and robustness of the system, and facilitate various levels of remote control by a human operator. The operator is normally located on the same surface vessel that prepares, launches, recovers and services the AUV.
While the vehicle is pre-programmed for its mission, and able to handle a large number of malfunctions and anomalies, the acoustic communications result in a higher level of confidence that the system works as programmed.

Recently (2006) the Hugin 4500 AUV (depth rated to 4500 m) has been added to the series of available models.

Development:
Kongsberg, Norway.

Status:
In use for civil purposes (Fugro, C&C).

Dimensions:
5.3m (17ft) in length and 1.0m (3.3ft) in diameter.

Sensors:
- Multibeam bathymetry.
- Sub-bottom profilers.
- Obstacle-avoidance sonars.
- Radio telemetry.
- Video.
- Altimeters.

Endurance:
A working fuel cell with a long endurance.
Mission duration of 50 hours at 4.0 knots.

Tasks:
Accurate and efficient seabed mapping.

Classification:
Location: Underwater.
Control: Autonomous (or Remotely Operated).
Function: Reconnaissance.

Table 14 Classification of Hugin 3000.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Control	ROV	Remotely Operated Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
The Hugin 3000 UUV offers several advantages to existing technology that include:
- Long range.
- Autonomous operation.
- Real-time data feedback.
- Proven launch-and-recovery system.
- System transportability.
- Proven capabilities as exhibited by its more than 30,000 linear kilometers of worldwide mapping performed during the past three years.

3.2.11 M600 / SeaOtter

Picture:

Source:
http://www.maridan.dk/
http://www.naval-technology.com/contractors/mine_disposal/atlas/
http://www.maridan.dk/product/SM0006%20BRO%20001%2002%20AUV%20Specification%2006012003.pdf

Description:
The M600 / SeaOtter Mk1 AUV offers high quality data. The deployment sea state is 5 and the recovery sea state is 6. The vehicle is designed for a variety of applications, including:

- Offshore oil and gas field surveys.
- Mineral field surveys.
- Telecommunication cable route surveys.
- Offshore pipeline pre-lay route surveys and post-lay inspections.
- Military surveys.
- Wind park construction surveys.
- Search and recovery.
- Oceanographic surveys.
- Data collection (data taxi).

The advanced version, the SeaOtter AUV (Mk2) is specially designed for various military purposes, strictly adhering to a modular approach with regard to superstructure, propulsion, energy, communication, navigation and payload. Its main tasks include:

- mine detection and countermeasures;
- covert intelligence, surveillance and reconnaissance;
- rapid environmental assessment (REA).

Development:
ATLAS MARIDAN ApS, Denmark.

Status:
M600/SeaOtter Mk I: in use (civil), SeaOtter Mk II: idea.

Dimensions:
In its current configuration, the vehicle length is 4.5 m and the dry weight of the vehicle, including batteries and standard payload sensors, is 1,700 kg.

Sensors:
- The Reson SeaBat 8125 is a wide-sector, wide-band focused multi beam sonar ever to be deployed.
- The side scan sonar is a digital, single beam, simultaneous dual frequency 100 kHz/500 kHz nominal (120 kHz, ±10% / 400 kHz, ±10% actual) from the Klein 2000 series.
- The modified GeoAcoustics GeoChirp is a sub-bottom profiling system for high resolution shallow geophysics, combined with state of the art electronics with standard proven technology. The system uses frequencies 2- 7 kHz for high penetration and 1.5 - 11.5 kHz for penetration.

Endurance:
7 hours at survey speed with a lead acid cell.

Tasks:
All tasks mentioned before including survey for diamantes (De Beers Marine, South Africa).

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 15 Classification of M600/SeaOtter.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
The M600/SeaOtter is multifunction for purposes as bottom classification, MCM and surveillance/reconnaissance. The M600/SeaOtter is developed for the purpose of tracing diamantes. The advanced version, the SeaOtter AUV (Mk2) is specially designed for various military purposes, strictly adhering to a modular approach with regard to superstructure, propulsion, energy, communication, navigation and payload. Its main tasks include:
- Mine detection and countermeasures.
- Covert intelligence, surveillance and reconnaissance.
- Rapid environmental assessment.

3.2.12 *Redermor AUV*

Picture:

Source:
CD UDT 2004,
http://www.worldofdefence.com/technical_library/technical_library_paper.ehtml?o=359
http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=725767

Description:
The Redermor AUV is based on an ROV platform previously developed during the French-UK collaboration project 'Remote Mine Hunting System'. This large platform is being enhanced with a very sophisticated propulsion and control system in order to provide hovering capabilities as well as high-speed performance. It is able to carry various payloads with minimum adaptation.

Redermor is an unmanned underwater vehicle (UUV) designed and manufactured by GESMA. This vehicle is now involved in the project Non traditional Navigation in order to increase the autonomy of UUV. Redermor could be considered as an experimental platform for ROV/AUV field sea trials.

Development:
Groupe d'Etudes Sous-Marine de l'Atlantique (GESMA), Brest, France.

Status:
Prototype.

Dimensions:
Length: 6 m, Diameter: 1 m, Weight: 4 t.

Sensors:
The Redermor platform is equipped with a KLEIN 5400 side scan sonar (455 kHz) and a RESON 8101 forward-looking sonar (240 kHz). The forward looking sonar will provide accurate speed information to the fusion filter while the side scan sonar will give information on the AUV position by seamarks feature mapping.

Endurance:
Unknown.

Tasks:
R&D testbed.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 16 Classification of Redermore AUV.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
This project is also driving works on optimization tools for mission planning and real time reconfiguration on events.

3.2.13 *REMUS AUV*

REMUS: Remote Environmental Monitoring Units

Picture:

Source:
http://www.whoi.edu/instruments/viewInstrument.do?id=1759

Description:
REMUS is an acronym for Remote Environmental Monitoring Units. These vehicles are robotic submarines resembling torpedoes that navigate without a human crew onboard and without cables connecting them to research vessels at the sea surface. The vehicles are designed for coastal monitoring as well as survey operations at various depths in the ocean. They are used widely for both scientific and military operations. Oceanographers use them as a vehicle to carry a wide variety of ocean instruments for data collection. Computers on the vehicle are used for system control, such as navigation and propulsion, as well as for data collection.

Development:
Woods Hole Oceanographic Institution (WHOI), Woods Hole, MA, USA.

Status:
In use.

Dimensions:
Length 63 in (160 cm), Width 7.5 in (19 cm), Weight 80 lbs. (36.5 kg).

Sensors:
- 12 kHz up/down-looking Acoustic Doppler Current Profiler (ADCP).
- Side scan sonar (usually 900 or 600 kHz).
- Conductivity, Temperature, Depth (CTD) sensor.
- An optical back-scatter sensor.
- Forward-looking sonar.
- Camera.
- Acoustic Doppler Velocimeter (ADV).

Endurance:
The Remus developed for tunnel inspection (TIV) completed the 15-hour survey.

Tasks:
Coastal monitoring.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 17 Classification of REMUS AUV.

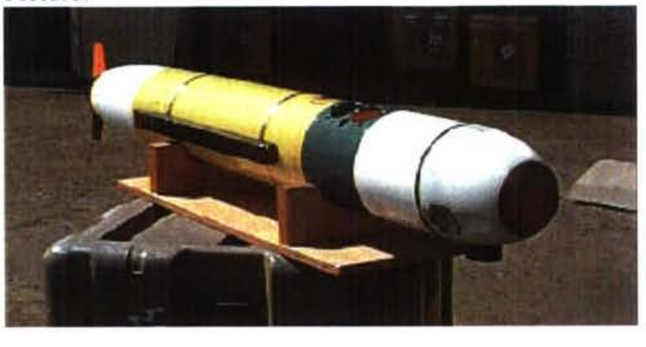
Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
Diversity of payload; both vehicle and operating costs are relatively low; and speed and accuracy of the survey exceed that of other platforms. REMUS can be configured with a diverse instrument suite such as a Fluor meter, bioluminescence sensor, radiometer, acoustic modem, forward-looking sonar, camera, plankton pump, Acoustic Doppler Velocimeter (ADV), and video plankton recorder.

3.2.14 *SAHRV*

SAHRV: Semi-Autonomous Hydrographic Reconnaissance Vehicle.

Picture:



Source:
http://web.nps.navy.mil/~brutzman/Savage/Robots/UnmannedUnderwaterVehicles/SAHRV-SemiAutonomousHydrographicReconnaissainceVehicle.pdf
http://www.onr.navy.mil/sci_tech/32/docs/sahrv.pdf

Description:
The SAHRV is being developed to conduct hydrographic reconnaissance and mine countermeasures in the VSW regime. The near-term goal is to develop a lightweight, low-cost SAHRV that is capable of conducting large-area hydrographic reconnaissance and MCM operations, including mine-like obstacle detection. The SAHRV will use commercial off-the-shelf (COTS) technologies that are integrated into a small, torpedo-shaped vehicle. SAHRV has the capability to be augmented with additional sensors, such as side-scan sonar, that may yield a mine detection and classification capability. The program will evaluate the degree to which SAHRV can fulfil VSW mine countermeasures requirements with a long term goal of developing an advanced Autonomous Undersea Vehicle (AUV) that includes mine classification and a limited mine neutralization capability.
Based on the Remote Environmental Monitoring Unit System (REMUS) developed by Woods Hole Oceanographic Institution (WHOI) under ONR support, the Semi-Autonomous Hydrographic Reconnaissance Vehicle (SAHRV) system is being cooperatively developed by the Naval Sea Command (NAVSEA) and the Office of Naval Research (ONR) to support Naval Special Warfare missions for the United States Special Operations Command (USSOCOM). The SAHRV vehicle is an unmanned underwater vehicle that performs reconnaissance (hydrographic and side-scan sonar surveys) in littoral waters, from the seaward edge of the surf zone into waters as deep as 100 meters.

Development:
Naval Sea Command (NAVSEA) and the Office of Naval Research (ONR).

Status:
Prototype / In use (Navy SEALs)?

Dimensions:
Length 63 in (160 cm), Width 7.5 in (19 cm), Weight 80 lbs (36.5 kg).

Sensors:
- Marine Sonics Side Scan Sonar (COTS Sonar; 600 or 1200 kHz).
- Acoustic Doppler / Conductivity Temp Depth (CTD) / Optical Backscatter Sensor (OBS).
- The primary navigation is by localization relative to long base line transponders. Navigation is additionally supported by an ultra short base line system, Doppler velocity log, and compass.

Endurance:
The SAHRV can operate over 20 hours on battery power before recharging and is capable of speeds over 2.5 meters per second.

Tasks:
Hydrographic reconnaissance, mine countermeasures (side scan sonar surveys) in the VSW regime (from the seaward edge of the surf zone into waters as deep as 100 meters).

Classification:
Location: Underwater.
Control: Autonomous (based on REMUS, see previous section).
Function: Reconnaissance.

Table 18 Classification of SAHRV.

Location-control	AUV	Autonomous Underwater Vehicle
Location-function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
The vehicle is small, capable of deployment by two people, simple to program, and can be launched and recovered from a small vessel without a crane or other special handling equipment.

3.2.15 *SAUV*

SAUV: Solar powered Autonomous Underwater Vehicle.

Picture:

Source:
http://www.falmouth.com/DataSheets/SAUVWeb.pdf
http://www.ausi.org/research/SAUVDesc.html

Description:
The SAUV II is a solar powered autonomous vehicle capable of operating on the surface or at water depths up to 500 meters. The vehicle is equipped with rechargeable lithium hydride batteries to allow maximum mission endurance even under conditions where minimal solar radiation is available.
A solar powered AUV (SAUV) prototype testbed is being developed as one type of AOSN (Autonomous Oceanographic Sampling System) data gathering platform. The solar powered autonomous system will come to the surface each day to recharge its onboard energy system and then undertake ocean data sampling activities during the nighttime hours. While on the surface, it can update its position using GPS and communicate with a remote user to offload acquired data and receive modifications to its onboard instructions. The developers are specifically focused on the problems that will arise when many of these vehicles are used simultaneously to gather data in a cooperative fashion.

Development:
Autonomous Undersea Systems Institute (AUSI), New Hampshire, USA (by order of ONR).

Status:
Prototype.

Dimensions:
Length: 2.3 m, Width: 1.1 m, Weight: 200 kg (in air).

Sensors:
CTD, Fluorometer, Dissolved Oxygen, pH.

Endurance:
Solar power allows 'unlimited' mission endurance. The rechargeable lithium hydride batteries allow maximum mission endurance even under conditions where minimal solar radiation is available.

Tasks:
- Long term oceanographic monitoring/profiling to depths up to 500 meters.
- Communications gateway to provide topside interface with underwater instrumentation.
- Long term reservoir water quality monitoring when equipped with appropriate sensors.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 19 Classification of SAUV.

Location-control	AUV	Autonomous Underwater Vehicle
Location-function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
Solar power allows 'unlimited' mission endurance.

3.2.16 *Seahorse UUV*

Picture:

Source:
https://www.navo.navy.mil/pao/fact_sheets/sams_seahorse.pdf
http://www.arl.psu.edu/capabilities/us_sea_syseng.html
http://www.navy.mil/navydata/cno/n87/usw/issue_16/seahorses_and_submarines.html

Description:
The Seahorse-Class Autonomous Underwater Vehicle (AUV) is an untethered, unmanned, underwater robotic vehicle, capable of preprogrammed independent operations from a host platform or shore facility. Typical littoral zone AUV area characterization surveys can be conducted at operational depths of 30 to 300 meters. The Seahorse AUV was designed to collect high-quality, precision located environmental data in the littoral regions of the world. The driving design considerations were reliability, ease of maintenance and cost effectiveness.

Development:
Seahorse was developed at the Pennsylvania State University Applied Research Laboratory (Penn State ARL) for the Naval Oceanographic Office (NAVOCEANO).

Status:
Prototype.
Penn State ARL delivered Seahorse 1, the vehicle planned for the SSGN Demonstration, to NAVOCEANO in October 2000. It executed its first operational survey from USNS Bruce C. Heezen (T-AGS-64) a year later. Seahorse 2 was delivered in October 2001 and is currently in underway testing. Penn State is also fabricating a third operational vehicle, Seahorse 3.
NAVSEA will deploy Seahorse in January 2003 from a USS Ohio (SSBN- 726)-class submarine.

Dimensions:
Length: 27 feet, 10 inches, Diameter: 38 inches, Displacement 10,000 pounds.

Sensors:
The vehicle is presently equipped with a 150-kHz sidescan sonar, a 300-kHz acoustic Doppler current profiler, a mast-mounted global positioning system antenna, and an inertial navigation system.

Endurance:
The AUV is currently powered with alkaline batteries and can operate for 72 hours at 4 knots for a nominal range of 300 nautical miles before requiring battery replenishment.

Tasks:
The Seahorse AUV was designed to collect high quality environmental data in the littoral regions of the world.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 20 Classification of Seahorse UUV.

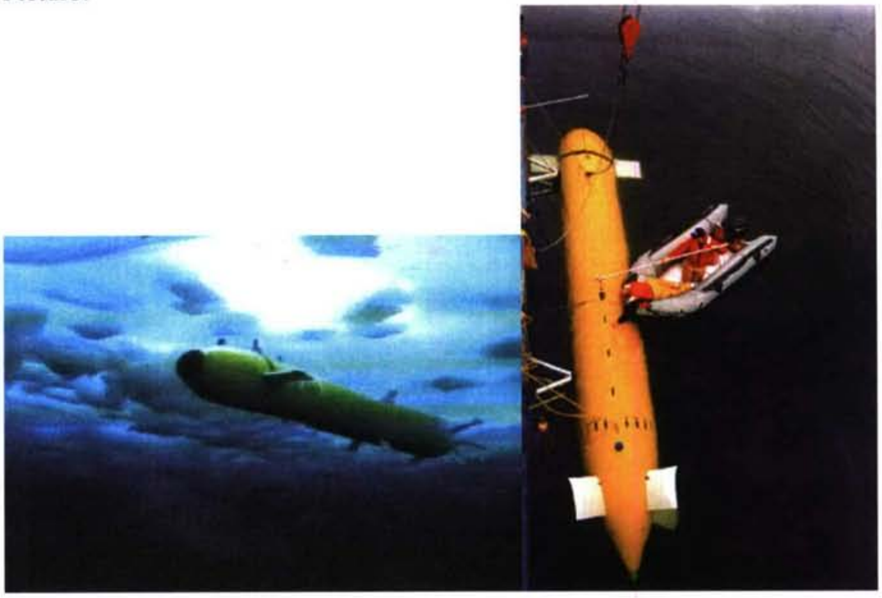
Location-Control	AUV	Autonomous Underwater Vehicle
Location-Function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:

-

3.2.17 *Theseus*

Picture:



Source:
http://www.ise.bc.ca/theseus.html

Description:
ISE Research Ltd commenced development of the Theseus AUV in 1992 under sponsorship of the Canadian Department of National Defence as part of a joint US-Canada Spinnaker project. The pressure hull payload bay and sensor suite of this AUV are configurable and can be adapted or replaced with new modules designed to support a wide variety of missions and tasks. The electric power source can also be sized to provide optimal cost effectiveness.

Development:
International Submarine Engineering (ISE) Research Ltd, Port Coquitlam, B.C. Canada.

Status:
In use.

Dimensions:
Length: 10.7 m, Diameter: 1.27 m, Displacement: 8600 kg (with 220 km cable).

Sensors:
- Doppler sonar.
- Acoustic transponder.
- Attachments for an umbilical and antenna.

Endurance:
During the 1996 deployment, a 190 km cable was laid in 500 meter depths under a 2.5 meter thick ice pack. The overall mission length was 365 km, making this the longest AUV mission to date.

Tasks:
The Theseus is developed to lay cables under the artic ice.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 21 Classification of Theseus.

Location-Control	AUV	Autonomous Underwater Vehicle
Location-function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
The Theseus is capable of tasks in rather extreme circumstances in which it has to cover large distances. It completed successful deployments to the Arctic in 1995 and 1996.

3.2.18 *Wayamba UUV*

Picture:

Source:
http://www.dsto.defence.gov.au/news/3282
http://www.dsto.defence.gov.au/news/3865

Description:
The Defence Science and Technology Organisation (DSTO) has spent more than $2 million on researching and developing a submersible unmanned underwater vehicle (UUV). The UUV is affectionately known as Wayamba, the aboriginal word for sea turtle. Wayamba was developed to be capable of carrying out research, deployments and communication tasks in today's military environment. UUVs are poised to play a major role in defence research, strategy and operations for decades to come.
The vehicle is equipped with a comprehensive range of on-board navigation, communications and surveillance sensors, with the capacity to carry quite large additional payloads.

Development:
Defence Science and Technology Organisation (DSTO), Australia.

Status:
Prototype.

Dimensions:
Length: 3 m, width 1.6 m, height 0.6 m.

Sensors:
- EDO 3050 doppler sonar (for transit).
- ORE LXT low frequency acoustic homing (for terminal).
- Sonatech STA-013-1 forward-looking sonar (for obstacle avoidance).

Endurance:
2 hours in transit, 4 to 5 hours on station.

Tasks:
Wayamba is a research vehicle to test concepts of operations and technologies for future defence applications of Autonomous Underwater Vehicles (for example mine hunting). Wayamba was developed to be capable of carrying out research, deployments and communication tasks in today's military environment.

Classification:
Location: Underwater.
Control: Autonomous.
Function: Reconnaissance.

Table 22 Classification of Wayamba UUV.

Location-control	AUV	Autonomous Underwater Vehicle
Location-function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
One of the key features of the Wayamba underwater vehicle technology is the ability to navigate and communicate with the outside world without the need to surface.
This is being achieved through a collaborative research project between DSTO and WA company Nautronix Ltd (NAS-HAIL through water communications).

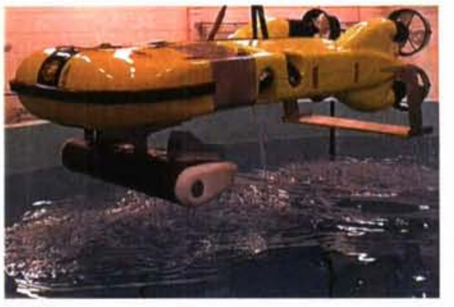
3.3 Underwater – Autonomous – Rescue

No systems with these categories have been identified.

3.4 Underwater – Remotely Operated – Combat

3.4.1 Double Eagle

Picture:



Source:
http://www.manw.nato.int/manw/pages/update/envision_3_02/sweden.htm
http://www.diabgroup.com/americas/u_opening/Solutions_01_04.pdf
http://www.saab.se/node5507.asp

Description:
The Saab Underwater Systems' Double Eagle is a lightweight (350 kg) system with eight thrusters that enable it to move forward even in 3 knot currents.
The Mark II version, developed since 1994, has a computerised stabilisation control system and its thrusters also provide considerable maneuverability with unlimited movement in 6° of freedom. The multirole philosophy means it can be equipped with a variety of sensors and tools including electronic scanning or conventional sonars, echo sounders, Doppler logs, automatic navigation system and manipulators. It has an unique precision charge-placing system and remains absolutely stable while the charge is being placed. The Double Eagle MkIII has a number of enhanced features that include 100% increased forward thrust for higher speed.
The Double Eagle is used by navies around the world on many types of ships.
It is controlled and powered via an umbilical cable from the mother ship rather than by telemetry so that its operating signals cannot be intercepted or corrupted.

Development:
Saab Underwater Systems, Sweden.

Status:
Mark I and II: in use, Mark III: prototype.

Dimensions:
Mk2: Length: 2.2 m, width:1.3 m, heigth: 0.5 m. operational depth: 300 m.
Mk3: Length: 3.0 m, width:1.3 m, heigth: 1.3 m. operational depth: 500 m.

Sensors:
- Mk II: Electronic scanning sonar (Other sonars may be fitted).
- three rate gyros, three pendulums, one fluxgate compass, one depth sensor; four leakage sensors, one speed log and one altimeter.

Endurance:
Mk II: Unlimited endurance due to power supply through the tether.
Mk III: 10 hours, Li Ion batteries.

Tasks:
The Double Eagle Mark III has been developed by SAAB Bofors to fulfil a variety of tasks including offshore exploration, environmental research, marine biology, power plant inspection and military duties. In the Netherlands the Double Eagle is being used as SPVDS (Self Propelled Variable Depth Sonar) which sails in front of a mine hunting vessel.

Classification:
Location: Underwater.
Control: Remotely Operated.
Function: Reconnaissance, combat.

Table 23 Classification of Double Eagle.

Location-Control	ROUV	Remotely Operated Underwater Vehicle
Location-function	URecUV	Unmanned Reconnaissance Underwater Vehicle
Location-function	UCUV	Unmanned Combat Underwater Vehicle

Expected specific advantage:
Large, flexible and stable platform. There is a lot of experience because it is in use by several different navies.

3.4.2 *Manta*

Picture:

Source:
http://www.chinfo.navy.mil/navpalib/cno/n87/usw/issue_15/wave.html

Description:
Futuristic concepts, such as Naval Undersea Warfare Center's Manta vehicle, would approach, or even exceed, the dimensions of today's Advanced SEAL Delivery System (ASDS) – 65 feet long and 55 tons. Vehicles of that dimension could carry a variety of

full-scale weapons – conceptually, Manta could launch heavyweight torpedoes and – depending on future rules of engagement – might even be unleashed to wield lethal force against enemy ships, submarines, and shore installations.
If actually developed, Manta would introduce revolutionary new concepts of submarine operations – and require corresponding changes in submarine design. Envisioned as large, somewhat ray-shaped vehicles as much as 50 feet long, four Mantas might be carried externally on future submarines by integrating them conformally into launch-and-recovery sites just behind the bow. With the ability to replenish their energy sources onboard and to change out the Mantas' modular mission packages as needed, the host submarine would gain extraordinary combat power, reach, and flexibility.
Moreover, the Manta payloads of torpedoes and other weapons would be available to the host as additional onboard resources as long as the UUVs remained attached. NUWC has already tested at sea a one-third scale Manta prototype capable of carrying multiple Mk 48 torpedoes, and they have also demonstrated its ability to launch smaller UUVs while underway. Manta remains an ambitious concept in the early stages of research and development, and implementing a Manta-like vision for future submarine warfare would require at least a concerted, decade-long effort.

Development:
Naval Undersea Warfare Center, USA.

Status:
Idea.

Dimensions:
65 feet long and 55 tons.

Sensors:
Tbd.

Endurance:
The Manta vehicle uses lead-acid batteries for propulsion and differential thrust for control to achieve ranges of 15 to 25 miles.

Tasks:
Anti Submarine Warfare.

Classification:
Location: Underwater.
Control: Remotely Operated.
Function: Combat.

Table 24 Classification of Manta.

Location-Control	ROUV	Remotely Operated Underwater Vehicle
Location-function	UCUV	Unmanned Combat Underwater Vehicle

Expected specific advantage:
One of the few unmanned ASW systems.

3.4.3 *PAP Mark 5*
PAP: Poisson Auto Propulsé

Picture:

Source:
http://www.eca.fr/

Description:
Remotely operated underwater vehicle for the identification and destruction of bottom-laid and tethered sea mines. By means of a guide-rope, the vehicle navigates in mid-water or at a constant altitude above the seabed. It is fitted with camera and/or sonar for visualisation and identification purposes. The mine is destroyed by the explosion of a 120 kg NATO charge and/or by cutting the mooring rope.

Development:
Eca, Toulon, France.

Status:
With over 500 vehicles operational in over 20 Navies of the world, the PAP is certainly the most known in the market place. The PAPs have carried out over 45,000 combat missions and have proved their efficiency in some of the major recent conflicts: Red Sea, Falkland, Persian Gulf, and Gulf War.

Dimensions:
Length 3160 mm, Width 120 mm, Height 125 mm.
Weight in air: 890 kg (with NATO charge).
Max operating depth: 300m.

Sensors:
It is fitted with camera and/or sonar for visualisation and identification purposes.

Endurance:
Max horizontal operating range: 2000m.

Tasks:
Identification and destruction of sea mines.

Classification:
Location: Underwater.
Control: Remotely Operated.
Function: Combat.

Table 25 Classification of PAP Mark 5.

Location-Control	ROV	Remotely Operated Underwater Vehicle
Location-function	UCUV	Unmanned Combat Underwater Vehicle

Expected specific advantage:
The system has been tested extensively; it is in use with many countries.

3.5 Underwater – Remotely Operated – Reconnaissance

3.5.1 *Double Eagle*
Described in Section 3.4.1.

3.5.2 *Hugin 1000*
Described in Section 3.2.9.

3.5.3 *Hugin 3000*
Described in Section 3.2.10.

3.5.4 *SSUS*
SSUS: Small-Size Unmanned Submersible.

Picture:

Source:
http://www.norilsk-telekom.ru/users/sfumato/

Description:
SSUS widely used by companies dealing with installation and operation of hydro structures and research work connected with water environment studies.
It may be used for sea tourism, where tourists are offered different tours on board of comfortable yachts, special routs by sailing boats, etc.

Development:
Norcom, Norilsk, Rusland.

Status:
In use.

Dimensions:
- Dimensions: 1.12 x 0.65 x 0.52 m.
- Mass: 60.0 kg.
- Maximum operation depth: 100 m.
- Speed limit: 2.0 m/s.

Sensors:
Basic equipment:
- Portable color videocamera, PAL: 1 pcs.
- Number and power of underwater lamps: 2 x 150 W.

Hydrophysical instrumentation:
- Hdrostatic pressure.
- Water thermometer.
- Eectric conduction transducer.
- Rdioactivity meter.

Hydrochemical instrumentation:
- pH meter.
- pS meter.
- potentiometer.

Samplers:
- Water sampler: 3 x 1.0 l.
- Ground sampler: 3 x 0.25 cube dm.

Process equipment:
- Cable cutter.
- Manipulator.
- Gripper.
- A kit of buoys.

Endurance:
Unlimited (power cable, 150 m).

Tasks:
- Inspection and video documentation of underwater structures (pipelines, tower, piles), as well as submerged parts of wharves, dikes and dams, etcetera.
- Inspection of submerged parts of vessels, floating docks afloat.
- Measurement of hydro physical and hydro chemical parameters of water medium.
- Sampling of water and bottom ground.
- Inspection and video documentation of bottom surface: bottom relief and its pollution level, detection of different objects, suspensions and stains that are ecologically dangerous for water area.
- Examination of port water area condition, as well as mapping of depth and video documentation of bottom relief.
- Cutting of cables, gripping and lifting up small items, performing simple technical underwater operations using small-size manipulator (underwater objects slinging, manipulator with threaded joints, etcetera).
- Remote measurement of the wall thickness of underwater oil and gas pipelines.
- Searching of sunken objects.

Classification:
Location: Underwater.
Control: Remotely Operated.
Function: Reconnaissance.

Table 26 Classification of SSUS.

Location-Control	ROUV	Remotely Operated Underwater Vehicle
Location-function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
?

3.5.5 *SUBROV*
Picture:

Source:
http://products.saab.se/PDBWeb/ShowProduct.aspx?ProductId=1299
http://products.saab.se/pdbweb/GetFile.aspx?pathtype=ProductFiles&filetype=Files&id=3229

Description:
The SUBROV system is intended for use from a submarine torpedo tube.
The SUBROV has a capability for inspection, UW-works as a communication platform and an active docking tool for an AUV.

Development:
Saab Underwater Systems, Sweden.

Status:
Idea.

Dimensions:
ROV Length 1.8 m.
Diameter 0.533 m.
ROV Weight 120 kg.
Power Supply (max) 5 kW.

Sensors:
The ROV is equipped with both color and low light cameras. The ROV is also equipped with a sonar to help navigation and to relocate objects.

Endurance:
The power supply is a converter that can transform the onboard battery supply to power for the ROV through the tether (length: 100 m).

Tasks:
Inspection
The system can be used to inspect both the submarine itself as well as the area surrounding the submarine. The ROV is equipped with both color and low light cameras. The ROV is also equipped with sonar to help navigation and to relocate objects.

Intervention
The ROV can be equipped with tools to perform various tasks such as cutting wires, retrieving or moving objects with a manipulator. The ROV can then move the AUV into a torpedo tube for recovery.
Communication
The system can be used to carry an antenna module that can be brought to the surface to establish radio communications. It can also be used to dock and connect to underwater communication nodes.
AUV Recovery
The ROV can be equipped with an AUV gripping tool allowing it to be used to dock with an incoming AUV. The ROV can then move the AUV into a torpedo tube for recovery.

Classification:
Location: Underwater.
Control: Remotely Operated.
Function: Reconnaissance.

Table 27 Classification of SubROV.

Location-Control	ROUV	Remotely Operated Underwater Vehicle
Location-function	URecUV	Unmanned Reconnaissance Underwater Vehicle

Expected specific advantage:
Generic platform developed to be used by a submarine.

3.6 Underwater – Remotely Operated – Rescue

Deep Drone-8000
Picture:

Source:
http://www.supsalv.org/00c2_deepDrone7200Rov.asp
http://en.wikipedia.org/wiki/Deep_Drone

Description:
The Deep Drone is a 7,200-foot depth rated Remotely Operated Vehicle (ROV). The system is designed to meet the Navy's needs for deep ocean recovery.
The system is air transportable on military cargo aircraft and is designed to operate from various ships. The vessel is outfitted with a sonar, two robotic arms, as well as TV and photo cameras.

Development:
Naval Sea Systems Command, USA.

Status:
In use (US Navy).

Dimensions:
Length - 9 ft, 3 in.
Width - 4 ft, 7 in.
Height - 6 ft, 2 in.
Weight - 4,100 lbs.

Sensors:
Sonar:
(1) CTFM (Continuous Transmission Frequency Modulated)with 2000 ft, max. Range with pinger locator (27/37.5/45kHz)
1 Mhz or 1.8 Mhz Multibeam (DIDSON)
Cameras:
- (1) 600-line SIT video wide angle Black and White (fixed).
- (1) 460-line color video on pan and tilt.
- (1) 360-line rear looking color with LED lights.
- 3.3-Meg Pixel Digital Sitll with strobe.

Endurance:
Unlimited (power cable from deck hydraulic power unit and generator).

Tasks:
Deep sea underwater recovery. The Deep Drone-8000 helped saving the crew from a Russian submarine in June 2005, see
http://english.pravda.ru/accidents/21/97/384/15931_minisub.html)

Classification:
Location: Underwater.
Control: Remotely Operated.
Function: Rescue.

Table 28 Classification of Deep Drone-8000.

Location-Control	ROUV	Remotely Operated Underwater Vehicle
Location-Function	URUV	Unmanned Rescue Underwater Vehicle

Expected specific advantage:
-

3.6.1 *Priz*

Picture:

Source:
http://www.globalsecurity.org/military/world/russia/1855.htm
http://en.wikipedia.org/wiki/Priz_class

Description:
There is very little known about Russian deep rescue systems. The Krasnoye Sormovo plant built four [some reports claim five] titanium-alloy Priz rescue submersibles able to accommodate 20 men and dive as deep as 1,000 meters. The Priz, about 44 feet long and 19 feet high, is believed to be operable in either manned or unmanned mode. Some sources suggest it has a battery endurance of only three hours. They produced diverse defense equipment, including rescue submarines 'Bester'and 'Priz'.
Due to lack of proper funds, this equipment was not upgraded since mid-1980s and nowadays is not used properly. Upgrades were proposed that would allow the sub to dock with damaged submarines, along with improvements to their navigation equipment. Note that the submarine which sank in Beryozovaya Bay in June 2005 was of the type Priz. Three days later the submarine and her crew could be saved.
The Unmanned Rescue vehicle had to be rescued itself.

Development:
Lazurit Central Design Bureau, Russia.

Status:
In use.

Dimensions:
13.5 m long, 3.8 m wide, 4.6 m tall, 55 ton displacement, 1000 m operational depth.

Sensors:
?

Endurance:
21 mi range. Some sources suggest it has a battery endurance of only three hours.

Tasks:
Deep sea underwater recovery.

Classification:
Location: Underwater.
Control: Remotely Operated.
Function: Rescue.

Table 29 Classification of Priz.

Location-control	ROUV	Remotely Operated Underwater Vehicle
Location-function	URUV	Unmanned Rescue Underwater Vehicle

Expected specific advantage:
-

3.6.2 *Super Scorpio*

Picture:

Source:
http://www.navsource.org/archives/08/08353.htm
http://en.wikipedia.org/wiki/Scorpio_ROV

Description:
The Unmanned Vehicles Detachment (UMV) was initially organized in the mid 1970s from personnel in the various departments of Submarine Development Squadron 5 and Deep Submergence Unit. UMV was first assigned a Side Looking Sonar (SILOS) system and a precision navigation system. These systems allowed UMV to begin search and survey operations, mostly in shallow water and near land. As deep ocean ROV technology continued to develop, UMV continued as well. In August of 1987, the unit's recovery capability was further extended with the delivery of the Super Scorpio Tethered Unmanned Work Vehicle System.

Development:
AMETEK Straza of San Diego, US.

Status:
In use (Royal Navy).

Dimensions:
Length: 2.43 meters.
Height: 1.22 meters.
Width: 1.22 meters.
Weight: 2,040 kg.

Sensors:
107-122kHz CTFM SONAR.

Endurance:
Unlimited (power cable).

Tasks:
The Scorpio is designed to rescue other submarines. In June 2005 it rescued a Priz class submarine which got jammed in a fishing net, see http://english.pravda.ru/accidents/21/97/384/15931_minisub.html)

Classification:
Location: Underwater.
Control: Remotely Operated.
Function: Rescue.

Table 30 Classification of Super Scorpio.

Location-Control	ROUV	Remotely Operated Underwater Vehicle
Location-function	URUV	Unmanned Rescue Underwater Vehicle

Expected specific advantage:
-

4 Inventory of different types of USSVs

In the previous chapter we identified UUVs for the categories control and function. In this chapter a similar thing will be done for USSVs.

4.1 Semi-submersible – Autonomous – Combat

No systems have been identified with these characteristics.

4.2 Semi-submersible – Autonomous – Reconnaissance

4.2.1 BASIL

BASIL: Bases Autopropulsées pseudo-Stationnaires en réseau Interconnecté de Localisation.

Picture:

Source:
http://www.ifremer.fr/flotte/coop_nationale/basil.htm
http://www.underwater-gps.com/dpbuoys/dpbuoys.htm

Description:
BASIL consists of a self-propelled intelligent GPS buoy with automated functionalities for dynamic positioning and programmed trajectory. It is remotely operated by a computer centre which receives the acoustic data as well as the GPS position by means of radio transmission. It is mainly used for positioning UUVs exploring oil fields.

Development:
Géocéan in cooperation with ACSA and Ifremer, all seated in France.

Status:
Prototype?

Dimensions:
Length: 2,5 m.
Height: 0,8 m.
Height antenna: 2 m.
Depth transducer: 2-15 m.
Speed: max 3 kts.
Autonomy: 7 days.

Sensors:
Acoustic transducer.

Endurance:
Autonomy: 3 hrs.

Tasks:
Underwater GPS to locate objects searching for oil fields.

Classification:
Location: Semi-submersible.
Control: Autonomous.
Function: Reconnaissance.

Table 31 Classification of BASIL.

Location-Control	ASSV	Autonomous Semi-Submersible Vehicle
Location-Function	URecSSV	Unmanned Reconnaissance Semi-Submersible Vehicle

Expected specific advantage:
The BASIL is capable to accurately determine the location of an underwater object.

4.2.2 *Dorado*

Picture:

Source:
http://www.ise.bc.ca/dorado.html

Description:
The growing threat from new-generation mines that are more difficult to detect has stimulated the demand for new mine hunting systems that offer improved safety and efficiency. The Dorado vehicle, owned by the Canadian Department of National Defence, was developed to meet this need. DCN International is selling the Dorado vehicle as part of their Forward Deployed Side Scan Sonar (FDS3 Remote MCM) system.
The Dorado vehicle is capable of towing a sonar tow fish at speeds up to 12 knots and

depths to 200 meters. It is powered by a 315 kW marine diesel engine. Air is drawn through the mast and exhausted through the stabilizer above the contra-rotating propeller. The engine also provides power for the hydraulically operated control planes and the keel mounted winch for the sonar tow fish.

Command and Control can be: manual, auto pilot, or autonomous DGPS based line-following between geo-graphic waypoints. The system has a 400-465 mHz 9600 baud full duplex communication radio with 5 asynchronous RS-232 ports.

Development:
International Submarine Engineering (ISE) Ltd, Port Coquitlam, BC, Canada.

Status:
In use.

Dimensions:
Length: 8.23 m.
Diameter: 2.28 m.
Dry weight: 5900 kg (fully fuelled).

Sensors:
DCN International, of France, is selling the Dorado vehicle as part of their Forward Deployed Side Scan Sonar (FDS3 Remote MCM) system.

Endurance:
12 hrs at 200 depth with tow. 28 hrs without tow.

Tasks:
Mine hunting.

Classification:
Location: Semi-submersible.
Control: Autonomous or Remotely Operated.
Function: Reconnaissance.

Table 32 Classification of Dorado.

Location-Control	ASSV	Autonomous Semi-Submersible Vehicle
Location-Control	ROSSV	Remotely Operated Semi-Submersible Vehicle
Location-Function	URecSSV	Unmanned Reconnaissance Semi-Submersible Vehicle

Expected specific advantage:
Since the hull of the vehicle is deeply submerged, drag is greatly reduced over that of a surface drone. This permits the vehicle to operate at higher speeds and over longer ranges than surface based drones of similar size. As the mast is the only part of the vehicle to be affected by sea state, the vehicle is much more stable in waves than surface drones or small vessels. This stability allows high-quality side scan sonar records to be obtained in elevated sea states at high speeds.

Since the vehicle has a surface piercing mast, it is able to operate and transmit sonar data over a radio data link, rather than a fixed umbilical or an acoustic telemetry link.

4.2.3 *SASS 6M*

SASS: Survey Autonomous Semi-Submersible.

Picture:

Source:
http://www.asv.org.uk/

Description:
This full scale prototype vehicle was designed and built with the backing of an EU SMART innovation award and used to prove not only the vehicle performance but also to test the novel use of construction materials and fabrication methods.
The vehicle has a speed of 12 knots and a payload capacity of 100 kg and was designed to be launched and recovered from a ship or to be deployed from shore. The vehicle can carry fixed sensors for above and below water surveillance, and deployable sensors such as small ROVs or AUVs for deeper water survey.

Development:
Autonomous Surface Vehicles (ASV), West Sussex, UK.

Status:
Prototype.

Dimensions:
Max speed: 12 kts.
Max payload: 100 kg.
Length: 5.5 m.
Mast height: ± 2 m.
Depth main vehicle: ± 2 m.

Sensors:
Towed synthetic aperture sonar.

Endurance:
?

Tasks:
- To replicate the data gathering capability of the ship to reduce ship's time required for a specified task.
- To remove sensors from noise, bubbles and pollution round the ship's hull.
- To remove personnel from areas of potential danger.
- To provide a link between surface control and submerged AUVs.

Classification:
Location: Semi-Submersible.
Control: Autonomous.
Function: Reconnaissance.

Table 33 Classification of SASS 6M.

Location-Control	ASSV	Autonomous Semi-Submersible Vehicle
Location-Function	URecSSV	Unmanned Reconnaissance Semi-Submersible Vehicle

Expected specific advantage:
- Low capital and running costs.
- Ease of handling, using standard equipment.
- Low noise, (to ICES recommendations for Fishery Research Ships).
- Stable operation at slow speeds.
- Carry, launch, control and recover daughter AUVs and ROVs.

4.3 Semi-submersible – Autonomous – Rescue

No systems of this type have yet been identified.

4.4 Semi-submersible – Remotely Operated – Combat

No systems of this type have yet been identified.

4.5 Semi-submersible – Remotely Operated – Reconnaissance

4.5.1 AN/WLD-1 RMS

RMS: Remote Mine hunting System.

Picture:

Source:
http://www.ncsc.navy.mil/Our_Mission/Major_Projects/Remote_Minehunting_System_Focus_Sheet.htm
http://www.lockheedmartin.com/data/assets/1022.pdf

Description:
The AN/WLD-1(V)1 Remote Mine hunting System (RMS) is an off-board system that is organic to the Battle Group. It has been designed to meet Fleet demand for beyond line-of-sight mine reconnaissance against bottom and moored mines in deep and shallow water regions of anticipated operating areas. The semi-autonomous system will detect, classify, and identify mines and record their precise location for avoidance and/or subsequent removal. The system has been designed to be integral to forces deployed anywhere in the world, providing a mine countermeasures capability to surface combatant forces in the absence of dedicated mine countermeasure forces.

Development:
Naval Surface Warfare Center, USA.

Status:
In use.

Sensors:
- Side-look sonars.
- Forward-look sonar.
- Gap-filler sonar.
- Volume-search sonar.
- Electro-optical laser imager for mine identification.

Dimensions:
7 m long. Max speed > 16 knots.

Sensors:
AN/AQS-14 Mine hunting sonar.
SeaBat forward-looking sonar.

Endurance:
High.

Tasks:
Detect, classify and identify mines.

Classification:
Location: Semi Submersible.
Control: Remotely Operated.
Function: Reconnaissance.

Table 34 Classification of AN/WLD-1RMS.

Location-Control	ROSSV	Remotely Operated Semi-Submersible Vehicle
Location-Function	URecSSV	Unmanned Reconnaissance Semi-Submersible Vehicle

Expected specific advantage:
In the development of the AN/WLD-1 RMS it is taken into account that a UV operates in a task group. For this purpose the RMS is developed to be deployed from surface vehicles. A significant part of the development costs have been used to integrate the RMS with surface vehicles as well as launch and recovery.

4.5.2 *DOLPHIN*

DOLPHIN: Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation.

Picture:

Source:
http://www.ise.bc.ca/dolphin.html

Description:
The DOLPHIN unmanned semi-submersible was developed by International Submarine Engineering Ltd to provide a stable sensor platform for operation in adverse sea states. Because it is a snorkeling diesel powered vehicle, DOLPHIN has significant range, speed, and communication advantages over fully submersible or surface vehicles of comparative displacement.

Development:
International Submarine Engineering (ISE) Ltd, Port Coquitlam, BC, Canada.

Status:
In use.

Dimensions:
Length: 7.3 m.
Diameter: 1.0 m.
Displacement: 2832 kg (fully fuelled).

Sensors:
Developed for sidescan sonar. Can carry AQS 14, AQS 20, TSM 2054 orKlein 5500.

Endurance:
26 hours at 12 knots.

Tasks:
Hydrographic, mine hunting.

Classification:
Location: Semi submersible.
Control: Remotely Operated.
Function: Reconnaissance.

Table 35 Classification of DOLPHIN.

Location-Control	ROSSV	Remotely Operated Semi-Submersible Vehicle
Location-Function	URecSSV	Unmanned Reconnaissance Semi-Submersible Vehicle

Expected specific advantage:

-

4.5.3 Dorado

The Dorado is described in Section 4.2.2

4.6 Semi-submersible – Remotely Operated – Rescue

No systems of this type have yet been identified.

5 Inventory of different types of USVs

5.1 Surface – Autonomous – Combat

5.1.1 Spartan Scout

Picture:

Source:
http://www.news.navy.mil/search/display.asp?story_id=10964
http://www.tica05.org/papers/allain_maguer.pdf
http://www.strategypage.com/dls/articles/200561415554.asp
http://www.defenseindustrydaily.com/2005/05/spartan-usvs-for-singapores-navy/index.php

Description:
Spartan is a modular, reconfigurable, multi-mission, high-speed, semi-autonomous unmanned surface vehicle (USV) capable of carrying payloads of 3,000 and 5,000 pounds for seven-and-11-meter craft, respectively. Integrated as an expeditionary sensor and weapons system designed to be a primary 'force-leveler 'against asymmetric threats, it enables a battle force commander to match inexpensive threats with an appropriate response. Spartan Scout meets a need for ship force protection. It can provide surveillance in a harbor, not only for Navy ships but also U.S. Coast Guard units responsible for port security. It can be modified for mine detection or anti submarine warfare. When equipped with Hellfire or Javelin missiles, it could attack other surface vessels or conduct precision strikes ashore.

Development:
Northrop Grumman (in assignment of NUWC).

Status:
Prototype/in use (US, Singapore).

Dimensions:
7 or 11-meter Rigid Hull Inflatable Boat (RHIB).

Sensors:
Day and night video cameras.
As part of its contribution to the project, the French armament procurement agency (DGA) is procuring an ASW mission module for the 7 m long USV. Thales Underwater Systems (TUS) has been selected to provide the FLASH dipping sonar to fulfil both operational and performance requirements for such an ASW mission.

Endurance:
48 hours.

Tasks:
The Spartan is a modular and generic platform and can be used for the following missions: MCM, littoral ASW, torpedo defence, Intelligence, Surveillance and Reconnaissance (ISR), and force protection.

Classification:
Location: Surface.
Control: Autonomous or Remotely Operated.
Function: Combat or Reconnaissance.

Table 36 Classification of Spartan Scout.

Location-Control	ASV	Autonomous Surface Vehicle
Location-Control	ROSV	Remotely Operated Surface Vehicle
Location-Function	UCSV	Unmanned Combat Surface Vehicle
Location-Function	URecSV	Unmanned Reconnaissance Surface Vehicle

Expected specific advantage:
The Spartan Scout has a more powerful navigation system (than the Protector USV), and is able to operate without an operator (by using GPS to move between specified locations). Spartan Scout is also designed to use different sets of equipment for different missions (detecting mines, Intelligence-Surveillance-Reconnaissance, Anti-Terrorism/Force Protection, destroying threats with the machine-gun, and Anti Submarine Warfare). Spartan Scout can stay out for up to 48 hours, depending on how much high speed (it can hit up to 80 kilometers an hour) running is done.
The Spartan is multifunctionally deployable. USVs provide increased sensor coverage in a network-centric environment, thus enabling a rapid establishment of battle space dominance while eliminating unnecessary risk to personnel and naval vessels.

5.1.2 *Stingray USV*

Picture:

Source:
http://www.exhibitions.sibat.mod.gov.il/IDEF/UploadDocs/elbit07.pdf
http://www.defense-update.com/products/s/stingray.htm

Description:
Stingray is a USV capable of operating autonomously or remotely controlled by an operator located at a station, either on the shore or on board a ship. The USV can carry different types of payloads up to 100 kg and may run at a speed of 40 knots in sea-state 2 and at a low speed in sea-state 3. Stingray can endure at sea for a period of up to 2 hours at low speed or 1.5 hours at maximum speed.

Elbit Systems unveiled its new Unmanned Surface Vehicle (USV) 'Stingray' at the IDEF-05 exhibition in Turkey. Stingray can perform autonomously or be remotely controlled by a single operator located at the shore station or onboard the ship.
The development is based on Elbit's extensive experience in the development and operation of unmanned air vehicles (UAVs) and mini UAVs. It is equipped with autonomous navigation and positioning capability, cruise sensors, and a stabilization system which prevents capsizing. It is equipped with day and night electro-optical stabilized payload. The USV is controlled from a portable control station, from which operators can monitor and operate the mission payloads and perform mission planning.

Development:
Elbit Systems, Haifa, Israel.

Status:
Prototype.

Dimensions:
Jet-ski sized.

Sensors:
Day and night electro-optical stabilized sensors.

Endurance:
2 hours at low speed or 1.5 hours at maximum speed.

Tasks:
The USV is designed for homeland security and coast guard applications including clearing shipping lanes and underwater search missions. Potential naval combat applications include target identification and intelligence, reconnaissance and surveillance (ISR) missions. Other applications include EW and ELINT.

Classification:
Location: Surface.
Control: Autonomous or Remotely Operated.
Function: Combat or Reconnaissance.

Table 37 Classification of Stingray USV.

Location-Control	ASV	Autonomous Surface Vehicle
Location-Control	ROSV	Remotely Operated Surface Vehicle
Location-Function	UCSV	Unmanned Combat Surface Vehicle
Location-Function	URecSV	Unmanned Reconnaissance Surface Vehicle

Expected specific advantage:
-

5.2 Surface – Autonomous – Reconnaissance

5.2.1 Owl Mark II

Picture:

Source:
http://www.globalatlantic.com/unmanned2.html
http://www.sarich.com/usv/USVBahrainReport/USVBahrain.html
http://www.nap.edu/books/0309096766/html/116.html

Description:
During 1992-1994, the Owl MK II was developed under Office of Special Technology (OST) EOD/LIC (Explosive Ordnance Disposal/Low Intensity Conflicts) proof of concept prototype program. This USV was built with Naval Special Warfare in mind. The OST USV included starlight, daylight and IR cameras and a commercial side scan sonar, utilized a commercial GPS for navigation and tracking and commercial single frequency radios for telemetry, control and data transmission. A commercial spread spectrum radio was installed for side scan data transmission as well as a commercial Robertson autopilot controlled the USV in the autonomous mode.
In a series of sea trials, the Sea Owl demonstrated the capability to perform mine hunting, water-side security, port and harbor surveillance, and maritime interception operations.

The Owl USV is a commercially available modification of ASH (Autonomous Search and Hydrographic Vehicle), with a low-profile hull for increased stealth and payload, operated in a remotely controlled mode. It has been used in demonstrations for marine reconnaissance in riverine and littoral situations.

The Unmanned Surface Vehicle (USV) is a small, rugged, remotely or autonomously controlled marine vehicle that has demonstrated the capability to conduct a wide variety of missions. It can rapidly be deployed from pier side or from a ship of opportunity, and is capable of operating over the horizon (OTH), in moderate sea states and in very shallow water. The USV's inherent low-observable characteristics make it difficult to detect with active or passive sensor systems. The USV is a generic platform capable of accepting a variety of mission specific payloads. Demonstrated capabilities include: optical reconnaissance of naval and coastal activities; remote shallow water hydrographic survey; and detection of submarines in littoral waters.

Development:
Office of Special Technology (OST).

Status:
Already in use by the DON (Department of the Navy).

Dimensions:
-

Sensors:
Starlight-, daylight- and IR cameras and a commercial side scan sonar.

Tasks:
Reconnaissance, surveillance.

Classification:
Location: Surface.
Control: Autonomous or Remotely Operated.
Function: Reconnaissance.

Table 38 Classification of OWL Mark II.

Location-Control	ASV	Autonomous Surface Vehicle
Location-Control	ROSV	Remotely Operated Surface Vehicle
Location-Function	URecSV	Unmanned Reconnaissance Surface Vehicle

Expected specific advantage:
Fast (> 30 kts).

5.2.2 *Spartan Scout*

The Spartan Scout is described in Section 5.1.1

5.2.3 *Stingray USV*

The Stringray USV is described in Section. 5.1.2

5.3 Surface – Autonomous – Rescue

No systems of this type have yet been identified.

5.4 Surface – Remotely Operated – Combat

5.4.1 Protector USV

Picture:

Source:
http://www.rafael.co.il/web/rafnew/products/nav-protector.htm

Description:
The Protector is an integrated naval combat system, based on unmanned, autonomous, remotely-controlled surface vehicles. Highly maneuverable and stealthy, the Protector can conduct a wide spectrum of critical missions, while eliminating unnecessary risk to personnel and capital assets. The Protector's anti-terror mission module payload includes sensors and weapon systems. The search radar and the Toplite electro-optical (EO) pod serve for detection, identification and targeting. The weapon systems are based on Rafael's Typhoon remotely-controlled, stabilized weapon station, capable of operating various small caliber guns. The stabilized weapon station is highly accurate, yielding excellent hit-and-kill probability. The Protector is mission reconfigurable through its plug-and-play design, allowing utilization of various mission modules, such as Force protection, Anti-terror surveillance and reconnaissance, Mine Warfare (MIW), Electronic Warfare (EW) and precision strikes. Protector USV is jointly developed with Aeronautics Defense Systems Ltd.

Development:
Rafael Armament Development Authority Ltd, Haifa, Israel

Status:
In use (Singapore).

Dimensions:
4 tons, 30 feet long.

Sensors:
Search radar and the Toplite electro-optical (EO) pod (Multi-Sensor Optronic Payload).

Tasks:
Force protection, surveillance.

Classification:
Location: Surface.
Control: Remotely Operated.
Function: Combat.

Table 39 Classification of Protector USV.

Location-Control	ROSV	Remotely Operated Surface Vehicle
Location-Function	UCSV	Unmanned Combat Surface Vehicle

Expected specific advantage:
The Protector can be used for several distinguishing tasks such as homeland security operations, mine counter measures, Force protection, Electronic Warfare, etc.

5.4.2 *RoboSki*

Picture:

Source:
http://www.thirdhemisphere.com/products/roboski/

Description:
The autonomous search and hydrographic (ASH) vehicle and the Roboski were developed in the 1990s, initially as jet-ski type target drones for ship self-defense training. They are now also used as reconnaissance vehicle testbeds. They operate as remotely controlled vehicles and therefore are confined to line-of-sight operation.

Development:
Robotek Engineering, Gainesville, Texas.
Third Hemisphere Interactive, Denton, Texas.

Status:
In use.

Dimensions:
Jet-ski size.

Sensors:
?

Endurance:
?

Tasks:
The Roboski is used as a training target to simulate fast moving threat in the littoral. It can also be used for surveillance in ports and for counter drug measurements.

Classification:
Location: Surface.
Control: Remotely Operated.
Function: Combat (self defence training target) or Reconnaissance.

Table 40 Classification of Roboski.

Location-Control	ROSV	Remotely Operated Surface Vehicle
Location-function	URecSV	Unmanned Combat Surface Vehicle
Location-function	URecSV	Unmanned Reconnaissance Surface Vehicle

Expected specific advantage:
- Up to 9 Roboski vehicles may be monitored and controlled from a single location.
- Vehicle position may be displayed in real time.
- Any number of maps may be viewed simultaneously. Maps may be zoomed, scrolled, and rotated.

5.4.3 *SAM III*

SAM: Self-propelled Acoustic Magnetic sweep

Picture:

Source:
http://www.kockums.se/SurfaceVessels/sam.html

Description:
The SAM system is a unique, unmanned mine sweep for programmable sweeping of magnetic and acoustic mines. The vehicle is remotely controlled from a ship or from land. SAM is an exceptionally effective supplement to mine hunting and mine sweeping

by MCMVs. The SAM proved its worth during Operation Desert Storm, when it was successfully used for mine sweeping by the US Navy.
A total of 15 SAMs have been delivered, among them seven to the Swedish Navy, four to the Japanese Navy and two to the US Navy.

Development:
Kockums, Karlskrona, Sweden.

Status:
SAM I and II: in use, SAM III: idea.

Dimensions:
LxWxH (m): 12.5 x 5.6 x 3.2.
Weight: 12 ton.
Water displacement: 12 ton.

Sensors:
None.

Endurance:
?

Tasks:
Mine sweeping

Classification:
Location: Surface.
Control: Remotely Operated.
Function: Combat.

Table 41 Classification of SAM III.

Location-Control	ROSV	Remotely Operated Surface Vehicle
Location-Function	UCSV	Unmanned Combat Surface Vehicle

Expected specific advantage:
The construction is extremely shock resistant and seaworthy, even under rough conditions. The SAM proved its worth during Operation Desert Storm, when it was successfully used for mine sweeping by the US Navy. The vehicle is remotely controlled from a ship or from land.

5.4.4 *SeaStar USV*

Picture:

Source:
http://www.blog.ca/index.php/borisnewz?tag=Geostrategy
http://www.aeronautics-sys.com/Index.asp?ArticleID=23&CategoryID=41&Page=1
http://www.aeronautics-sys.com/_Uploads/23seastar(2).pdf

Description:
The SeaStar is an unmanned naval combat system that presents a revolution in maritime operations featuring unmanned capabilities for the entire range of Naval and Coast Guard missions. The SeaStar is highly autonomous and can perform a wide variety of missions, while eliminating unnecessary risk to personnel or capital assets. The SeaStar can be operated in hazardous sea conditions.

Development:
Aeronautics Defense Systems Ltd, Yavne, Israel.

Status:
Prototype/in use?

Dimensions:
Length: 11 m , width: 3.5 m.

Sensors:
- Day/night (EO/IR) sensors.
- Target acquisition sensors.
- ESM/ECM ELINT/COMINT.
- Sonar.

Endurance:
Mission Range: 300 nm + 10 hr holding.

Tasks:
Harbour and Strategic Facility Protection, Coast patrol, Ship Protection, Oil rig Protection, Optical and Electro-Magnetic field of sight extension, ISR missions, Target designation, Jamming and Decoy Missions, Electronic warfare operations, Force Protection.

Payloads:
- Day/night (EO/IR) sensors.
- Target acquisition sensors.
- ESM/ECM ELINT/COMINT.
- Sonar.
- Public address system.
- Non-lethal weapon Systems (Water/Noise/Stun).
- Maritime stabilized Gun and Fire control system.

Classification:
Location: Surface.
Control: Remotely Operated.
Function: Reconnaissance/Combat.

Table 42 Classification of SeaStar USV.

Location-Control	ROSV	Remotely Operated Surface Vehicle
Location-Function	UCSV	Unmanned Combat Surface Vehicle
Location-Function	URecSV	Unmanned Reconnaissance Surface Vehicle

Expected specific advantage:
Is capable of deploying both lethal and non-lethal weapons.

5.4.5 *Spartan Scout*

The Spartan Scout is described in Section 5.1.1.

5.4.6 *Stingray USV*

The Stingray USV is described in Section 5.1.1.

5.4.7 *Troika MCM System*

Picture:

Source:
http://www.luerssen.de/php/ship.php?pageid=13245

Description:
The challenge of sweeping mines without endangering the parent MCM vessel and her crew has been fully met with the Troika MCM system. The MCM vessel acts as the Control Ship for up to four unmanned surface drones called simulation sweeping craft (SSC). The SSC are remotely controlled to simulate magnetic and acoustic influences in order to trigger the firing mechanisms and to detonate the mines. The Control Ship stays safely outside the minefield during this operation. The SSC are of extremely sturdy and shock-resistant construction. They are self-propelled and driven by a diesel engine achieving speeds up to 10 knots and a range of about 1000 miles. Five German mine sweepers, type SM 343, have been recently converted to Advanced Troika Control Ships for the German Navy. These MCMVs are now designated HL 352 (Ensdorf-class).

Development:
Lürssen Werft GmbH, Bremen, Duitsland.

Status:
In use.

Dimensions:
Length about 25 m.

Sensors:
None.

Endurance:
1000 miles at 10 knots.

Tasks:
Mine sweeping.

Classification:
Location: Surface.
Control: Remotely Operated.
Function: Combat.

Table 43 Classification of Troika MCM system.

Location-Control	ROSV	Remotely Operated Surface Vehicle
Location-Function	UCSV	Unmanned Combat Surface Vehicle

Expected specific advantage:
The Advanced Troika MCM system overcomes the limitations of existing mine hunting systems, when bottom or water conditions are unfavorable. The system means increased safety for the valuable MCMV and her crew. It also offers a much improved sweeping performance which includes a higher sweeping rate because of the simultaneous operations of four drones with speeds up to 10 knots.

5.5 Surface – Remotely Operated – Reconnaissance

5.5.1 Owl Mark II
The Owl Mark II is described in Section 5.2.1.

5.5.2 RoboSki
The RoboSki is described in Section 5.4.2.

5.5.3 SeaStar USV
The SeaStar USV is described in Section 5.4.4.

5.5.4 Spartan Scout
The Spartan Scout is described in Section 5.1.1.

5.5.5 Stingray USV
The Stingray USV is described in Section 5.1.2.

5.6 Surface – Remotely Operated – Rescue

No systems of this type have yet been identified.

6 Tasks, capabilities and subcapabilities of the Royal Netherlands Navy

6.1 The task and capability list of the Royal Netherlands Navy

The task and capability list of the Royal Netherlands Armed Forces consists of 35 tasks and 95 capabilities. These capabilities refer to separate naval, land and aerial, as well as to joint and combined tasks and capabilities. The list in its entirety was published by the Netherlands' Ministry of Defence (see [2]). In [3] the defence capabilities relevant for naval operations were selected. This selection was taken as a starting point for the current study, in which the capabilities of the Royal Netherlands Navy which are relevant for UVs have been analysed. The selected naval defence capabilities can also be found in Appendix A.

6.2 Subcapability list in addition to the task and capability list

The following capabilities have been indicated as relevant for the Royal Netherlands Navy regarding UVs. Because the capabilities are rather a definition than a description, we decided to further develop the capabilities into subcapabilities. For all UVs we then analyse whether it is able to fulfil the defined subcapabilities which is done in the following chapter. It should be noticed that it can occur that a UV only fulfils some of the subcapabilities within a capability as a whole.
Some of the subcapabilities do not seem to be relevant for UVs at all and have not been further developed. For instance, it is clear that a UV is not able to board a ship, whereas boarding is a competence under ASuW.

Note that in the tables the following three definitions have been used.

1) Frequency ranges for active sonar:
- Frequency < 10 kHz: ASW.
- 10 kHz < frequency < 100 kHz: diver detection.
- Frequency > 100 kHz: MCM.

2) Types of sensors:

	Act. EM (Radar)	Visual (Eye)	IR (IRST)	Pass. EM (ESM)	Laser	Active Acoustic	Passive Acoustic
Above water	x	x	x	x	x		
Under water		x			x	x	x

3) Signal processing:
Low capability means simple processing.
High capability means advanced processing.

DC 13 Air surveillance:

Subcapability	Description	Requirement
Patrol	Travel (predetermined) route.	Active low capability sensor and long endurance.
Detect	Determine presence of contact.	Low capability sensor
Localise	Determine position, course and speed of contact.	Active low capability sensor.
Recognise	Determine the type of the contact (for instance military or commercial).	High capability sensor.
Identify	Determine the identity of the contact (hostile, friendly, neutral).	High capability sensor.
Track/monitor	Keep contact within track.	High speed, endurance and low capability sensor.

DC 22 ASW:

Above water target:

Subcapability	Description	Requirement
Search	Travel (predetermined) route in order to find something detected by another party.	High capability sensor.
Detect	Determine the presence of something.	High capability sensor.
Localise	Determine position, course and speed.	Active low capability sensor.
Classify	Determine whether detected contact is submarine's mast or not.	High capability sensor, for example imaging radar, visual sensor, infrared and ESM.
Act/Engage	Fire weapon (torpedo).	Visual and/or infrared sensor, gun and/or non-lethal weapon.
Track/monitor	Keep contact within track.	Low frequency (large sensor range), low capability sensor and/or high speed, and long endurance.
Assess	Determine the amount of damage inflicted.	Visual, damage / kill assessment, stealth. High capability sensor.
Disseminate	Communicate to main platform.	Radio link.

Under water target:

Subcapability	Description	Requirement
Search	Travel (predetermined) route in order to find something detected by another party.	Low frequency, low capability sensor.
Detect	Determine the presence of something.	Low frequency, low capability sensor.
Localise	Determine position, course and speed.	Low frequency, low capability sensor.
Classify	Determine whether detected contact is submarine or not.	High frequency, high capability sensor, for example imaging radar, visual sensor.
Act/Engage	Fire weapon (torpedo).	Torpedo with high frequency active sonar. Visual and/or non-lethal weapon.
Track/monitor	Keep contact within track.	Low frequency (large sensor range), low capability sensor and/or high speed, and long endurance.
Assess	Determine the amount of damage inflicted.	Visual, damage / kill assessment, stealth. High capability sensor.
Disseminate	Communicate to main platform	Cable, low frequency active acoustic sensor (underwater telephone) and/or radio link.

DC 23 ASuW[1]:

Above water:

Subcapability	Description	Requirement
Patrol	Travel (predetermined) route.	active low capability sensor and long endurance.
Search	Travel (predetermined) route in order to find something detected by another party.	low capability sensor.
Detect	Determine the presence of something.	low capability sensor.
Localise	Determine position, course and speed.	active low capability sensor.
Recognise	Determine the type of the contact (for instance military or commercial).	high capability sensor.
Identify	Determine the identity of the contact (hostile, friendly, neutral).	high capability sensor.
Track/monitor	Keep contact within track.	either a passive low capability sensor or a high capability sensor, high speed and endurance.
Interrogate	Establish communication with ship.	Radio link, IFF, loudspeaker.
Intercept	Travel route to block the ship's way.	High speed, deterrence capability (gun, non-lethal weapon, etcetera) and an arbitrary sensor.
Act/Engage/ Intervene	Fire weapon.	Arbitrary sensor, gun and/or non-lethal weapon.
Assess	Determine the amount of damage inflicted.	High capability sensor and gun and/or non-lethal weapon.
Apprehend		Arbitrary sensor, loudspeaker and weaponry (gun, non-lethal weapon, etcetera).
Disseminate	Communicate to main platform	Radio link
Revisit	Travel route to redetect the ship.	Either a passive low capability sensor or a high capability sensor, high speed and endurance.

[1] Subcapabilities board and seize are not relevant for UVs.

Under water:

Subcapability	Description	Requirement
Patrol	Travel (predetermined) route.	Passive low capability sensor and long endurance
Search	Travel (predetermined) route in order to find something detected by another party.	Passive low capability sensor
Detect	Determine the presence of something.	Passive low capability sensor
Localise	Determine position, course and speed.	Passive low capability sensor
Classify	Determine the type of the contact (for instance military or commercial).	Passive high capability sensor
Identify	Determine the identity of the contact (hostile, friendly, neutral).	Passive high capability sensor
Track/monitor	Keep contact within track	Passive low capability sensor
Interrogate	Establish communication with ship.	Radio link, IFF, loudspeaker
Intercept	Travel route to block the ship's way.	High speed, deterrence capability (gun, non-lethal weapon, etc) and an arbitrary sensor
Act/Engage/ Intervene	Fire weapon.	Arbitrary sensor, gun and/or non-lethal weapon.
Assess	Determine the amount of damage inflicted.	High capability sensor and gun and/or non-lethal weapon.
Apprehend		Arbitrary sensor, loudspeaker and weaponry (gun, etcetera)
Disseminate	Communicate to main platform	Radio link
Revisit	Travel route to redetect the ship.	Passive low capability sensor

DC 47 Electronic INTEL[2]:

Subcapability	Description	Requirement
Collect INTEL	To collect intelligence from the electro magnetic spectra transmitted by radio communication	High capability passive EM sensor (ESM).

[2] Subcapability analyse INTEL is not relevant for UVs (places a great strain on the real time link).

DC 54 Border patrol:

Above water:

Subcapability	Description	Requirement
Patrol	Travel (predetermined) route.	Active low capability sensor and long endurance
Detect	Determine the presence of something.	Low capability sensor
Localise	Determine position, course and speed.	Active low capability sensor
Recognise	Determine the type of the contact (for instance military or commercial).	High capability sensor
Identify	Determine the identity of the contact (hostile, friendly, neutral).	High capability sensor
Interrogate	Establish communication with ship.	Communication (radio link), IFF, loudspeaker
Intercept	Travel route to block the ship's way.	High speed, deterrence capability (gun, non-lethal weapon, etcetera) and an arbitrary sensor
Act/Engage/ Intervene	Fire weapon.	Arbitrary sensor, gun and/or non-lethal weapon.
Assess	Determine the amount of damage inflicted.	High capability sensor and gun and/or non-lethal weapon
Apprehend		Arbitrary sensor, loudspeaker and weaponry (gun, etc)
Disseminate	Communicate to main platform	Radio link

Under water:

Subcapability	Description	Requirement
Patrol	Travel (predetermined) route.	Passive low capability sensor and long endurance
Detect	Determine the presence of something.	Passive low capability sensor
Localise	Determine position, course and speed	Passive low capability sensor
Classify	Determine the type of the contact (for instance military or commercial).	Passive high capability sensor
Identify	Determine the identity of the contact (hostile, friendly, neutral).	Passive high capability sensor
Interrogate	Establish communication with ship.	Communication (radio link), IFF, loudspeaker
Intercept	Travel route to block the ship's way.	High speed, deterrence capability (gun, non-lethal weapon, etcetera) and an arbitrary sensor
Act/Engage/ Intervene	Fire weapon.	Arbitrary sensor, gun and/or non-lethal weapon.
Assess	Determine the amount of damage inflicted.	High capability sensor and gun and/or non-lethal weapon.
Apprehend		Arbitrary sensor, loudspeaker and weaponry (gun, non-lethal weapon, etcetera)
Disseminate	Communicate to main platform	Radio link

DC 57 Harbour defence:

Diver

Subcapability	Description	Requirement
Patrol	Travel (predetermined) route.	High frequency active sonar, long endurance.
Search	Travel (predetermined) route in order to find something detected by another party.	High frequency active sonar.
Detect	Determine the presence of something.	High frequency active sonar.
Localise	Determine position, course and speed.	High frequency active sonar, accurate positioning.
Act/Engage/ Intervene	Fire weapon.	Underwater weapon (lethal, non-lethal, for instance noise, flashbang, net, rubber bullet, ink), any underwater sensor (for targeting)

IED

Subcapability	Description	Requirement
Search	Travel (predetermined) route in order to find something detected by another party.	Very high frequency high capability active sonar.
Detect	Determine the presence of something.	Very high frequency high capability active sonar.
Localise	Determine position, course and speed.	High frequency active sonar, accurate positioning.
Investigate	Investigat the nature of the object.	Chemical sensor, visual sensor, electromagnetic sensor.
Remove	Relocate the object (to a safer place).	Robotic arm, 'blanket', 'bubble curtain'. (the last two are to minimise the effects of an unexpected explosion)
Deactivate	Destroy the object using explosives.	Explosive charge, remote actuation signal (acoustic or magnetic) in order to explode the IED from a certain distance.

Illegal above water object (e.g. jetski)[3]*:*

Subcapability	Description	Requirement
Patrol	Travel (predetermined) route.	Active above water sensor, long endurance.
Search	Travel (predetermined) route in order to find something detected by another party.	Active above water sensor.
Detect	Determine the presence of something.	Active above water sensor.
Localise	Determine position, course and speed.	Active above water sensor, GPS.
Recognise	Determine the type of the contact (for instance military or commercial).	Active high capability above water sensor (e.g. imaging radar).
Identify	Determine the identity of the contact (hostile, friendly, neutral).	Visual sensor.
Track/monitor	Keep contact within track	Active above water sensor.
Interrogate	Establish communication with ship.	Communication means (radio, megaphone), IFF.
Intercept	Travel route to block the ship's way.	High speed, high manoeuvrability.
Act/Engage/ Intervene	Fire weapon.	Weapon (lethal, non-lethal), any sensor (for targeting).
Assess (damage)	Determine the amount of damage inflicted.	High capability above water sensor.
Apprehend	Take people into custody.	Weapon (lethal, non-lethal), any sensor, communication means (radio, megaphone).
Disseminate	Communicate to main platform.	Communication means (radio).
Revisit	Travel route to redetect the ship.	Active above water sensor.

DC 62 Coast guard:

See DC 23 ASuW and DC 84 SAR.

[3] Harbour Defence against illegal above water objects differs from ASuW because the required sensor ranges inside the harbour are much smaller, therefore high capability (small range) sensors may also be effective.

DC 65 Maritime Mine Counter Measures capability:

Subcapability	Description	Requirement
Detect	Determine the presence of something.	High frequency high capability active sonar.
Localise	Determine position.	High frequency low capability ctive sonar, accurate positioning (< 5m)
Classify	Determine whether the contact is a mine or not.	Very high frequency high capability active sonar.
Identify	Confirm visually that the contact is a mine.	Visual.
Neutralise	Destroy the mine.	Explosive charge, shaped charge, remote actuation (acoustic and/or magnetic), robotic arm, cutter (scissors).
Influence sweeping	Generate ship like influences in order to fool mines.	Signature generation (Acoustic, Magnetic, Pressure, Electric).
Mechanical sweeping	Cut mooring cables of moored mines.	Sufficient engine power.
Jamming	Disturb the sensors of mines by generating 'noise'.	Environmental jamming: noise generation (Acoustic, Magnetic, Pressure, Electric). Signature jamming (lead-through): signature generation (Acoustic, Magnetic, Pressure, Electric).

DC 69 Hydrographics:

Subcapability	Description	Requirement
Collect	Hydrographics describes the bottom of the sea and the water column.	Many sensors are possible, among which: acoustic sensor (bottom mapping, bottom penetrating), sensors for waterdepth, sound speed, salinity, CTD, pressure, temperature, the flow of the water, robotic arm with a scoop, crawler, accuratepositioning.
Analyse	Not relevant for UVs	

DC 74 Naval Co-operation:

Subcapability	Description	Requirement
Track/monitor friendly forces	Keep contacts within track.	AIS (Automatic Identification System), low capability sensor, georeference system (sea chart)
Advise	Not relevant for UVs	

DC 84 SAR:

Above water target (drowning person):

Subcapability	Description	Requirement
Transit	Travel towards reported position.	High speed.
Search	Travel (predetermined) route in order to find drowning person.	High capability sensor.
Detect	Determine the presence of something.	High capability (precision) sensor.
Identify	Determine if contact is drowning human or not.	High capability sensor.
Recover	Take drowning / drowned person aboard.	Enough space to accommodate people.
Rescue living beings) / salvage (dead bodies)	Bring drowning / drowned person home safely.	First aid toolkit, enough space to rescue people, speed.

Under water target (submarine):

Subcapability	Description	Requirement
Transit	Travel towards reported position.	High speed.
Search	Travel (predetermined) route in order to find something detected by another party.	Low capability active sonar.
Detect	Determine the presence of something.	Low capability active sonar.
Identify	Determine if contact is submarine or not.	Low capability active sonar.
Investigate	Investigate the submarine for ways of rescuing the crew.	Visual and/or high capability high frequency active sonar.
Recover	Take drowning / drowned person aboard.	Enough space to accommodate people, oxygen, robotic arm, cutter (scissors).
Rescue (living beings) / salvage (dead bodies)	Bring drowning / drowned person home safely.	First aid toolkit, enough space to rescue people, oxygen, speed.

DC 85 Sea surveillance:

See DC 23 ASuW

DC 87 Signal intelligence capability (COMINT)[4]:

Subcapability	Description	Requirement
Collect INTEL	To collect intelligence from communication (radio and/or email) from third parties	Low capability passive RF sensor (monitoring equipment).

[4] Subcapability 'Analyse INTEL' is not relevant for UVs (places a great strain on the real time link).

7 Projection of UV inventory on task, capability and subcapability list

In this chapter the inventory of UVs from Chapters 3, 4 and 5 is projected on the subcapability list from the previous chapter.

7.1 Approach

In the remainder of this chapter we will link the UVs to the subcapabilities. In the tables, an 'x' in a cell means that the concerning UV can provide the corresponding subcapability.

To check whether the UV can provide the corresponding subcapability we check the following steps:
In Chapter 6 the capabilities and the accompanying subcapabilities are described in tables. In these tables the descriptions and the requirements for the subcapabilities are given. The requirements to provide a subcapability are mostly sensors and endurance requirements.
In chapters 3, 4 and 5 in the UV description the sensor and endurance capabilities of the UV are given. The combination of the subcapability requirements and the available sensors and endurance limitations of the system results in a conclusion whether the UV is able to provide the corresponding subcapability.
For example the ARCS is described. The ARCS has the following sensors: an EDO 3050 Doppler sonar and an ISE Mesotech 200 kHz obstacle avoidance sonar.
The only sensors available at the ARCS are two sonar systems. The first DC in the list where we find a required sonar for a subcapability is DC 57 harbour defence. The subcapabilities patrol, search, detect and localize for the diver part of this DC require a high frequency active sonar. This sonar is available for the ARCS system: the EDO 3050 Doppler sonar. Because of this the ARCS is able to provide these subcapabilities, so an 'x' is shown in the table with subcapabilities. For the subcapability act/engage/intervene an underwater weapon is required. The ARCS does not have an underwater weapon, so the ARCS is not able to provide this subcapability.
An other example in this research is the PAP Mark 5. A more detailed look at DC 65 MMCM is given. The first subcapability of this DC (detection) requires a high frequency and high capability active sonar. The PAP Mark 5 only has a camera and/or sonar for visualisation and identification purposes. So the PAP Mark 5 is not able to provide the subcapability detection. But the PAP Mark 5 is able to identify because it has a visual system. The PAP also has a 120 kg NATO charge, so it can provide subcapability neutralise because an explosive charge is required for that.

7.2 Linking the capabilities to UUVs

In the following table the relevant capabilities of the Royal Netherlands Navy are linked to the autonomous UUVs described in Chapter 3.

		Underwater Autonomous Combat AMPS	EMATT/ SUBMATT	Underwater Autonomous Reconnaissance ARCS	AUSS	Autosub -1	BPAUV	Cetus II	DeepC	Flying Plug	Gavia AUV	Hugin 1000	Hugin 3000	M600/ SeaOtter	Redermor AUV	REMUS AUV	SAHRV	SAUV	Sea-horse	Theseus	Waya mba
DC 13 - Air Surveillance	Patrol																				
	Detect																				
	Localise																				
	Classify																				
	Recognise																				
	Identify																				
	Track/monitor																				
DC 22 - ASW	Search																				
(snorting submarine)	Detect																				
	Localise																				
	Classify																				
	Act/Engage																				
	Track/monitor																				
	Assess																				
(submerged submarine)	Search																				
	Detect																				
	Localise																				
	Classify																				
	Act/Engage																				
	Track/monitor																				
	Assess				x						x										
DC 23 - ASuW	Patrol																				
	Search																				
	Detect																				
	Localise																				
	Classify																				
	Recognise																				
	Identify																				
	Track/monitor																				
	Interrogate																				
	Intercept																				
	Act/Engage/ Intervene																				
	Assess																				
	Apprehend																				
	Revisit																				
DC 47 - ELINT	Collect INTEL																				

		Underwater Autonomous Combat AMPS	EMATT/ SUBMATT	Underwater Autonomous Reconnaissance ARCS	AUSS	Autosub -1	BPAUV	Cetus II	DeepC	Flying Plug	Gavia AUV	Hugin 1000	Hugin 3000	M600/ SeaOtter	Redermor AUV	REMUS AUV	SAHRV	SAUV	Sea horse	Theseus	Waya mba
DC 54 - Border Patrol	Patrol																				
(above water)	Detect																				
	Localise																				
	Classify																				
	Recognise																				
	Identify																				
	Interrogate																				
	Intercept																				
	Act/Engage/ Intervene																				
	Assess																				
	Apprehend																				
DC 57 – Harbour defence	Patrol			x	x	x	x		x		x	x	x			x					
(diver)	Search			x	x		x		x		x	x	x			x					
	Detect			x	x		x		x		x	x	x			x					
	Act/Engage/ Intervene																				
(IED)	Search			x	x	x	x		x		x	x	x			x					
	Detect			x	x	x	x		x		x	x	x			x					
	Investigate				x						x					x					
	Remove																				
	Deactivate																				
(Above water object)	Patrol																				
	Search																				
	Detect																				
	Localise																				
	Recognise																				
	Identify																				
	Track/monitor																				
	Interrogate																				
	Intercept																				
	Act/Engage/ Intervene																				
	Assess																				
	Apprehend																				
	Revisit																				

		Underwater Autonomous Combat AMPS	EMATT/ SUBMATT	Underwater Autonomous Reconnaissance ARCS	AUS S	Autosub -1	BPAU V	Cetus II	DeepC	Flying Plug	Gavia AUV	Hugin 1000	Hugin 3000	M600/ SeaOtter	Redermor AUV	REMUS AUV	SAHRV	SAUV	Sea horse	Theseus	Waya mba
DC 62 - Coast guard	Patrol																				
	Search																				
	Detect																				
	Localise																				
	Classify																				
	Recognise																				
	Identify																				
	Track/monitor																				
	Interrogate																				
	Intercept																				
	Act/Engage/ Intervene																				
	Assess																				
	Apprehend																				
	Revisit																				
DC 65 - MMCM	Detect			x	x	x	x	x	x		x	x	x	x	x	x	x		x		x
	Localise			x	x	x	x	x	x		x	x	x	x	x	x	x		x		x
	Classify			x	x	x	x	x	x		x	x	x	x	x	x	x		x		x
	Identify				x	x		x	x		x	x	x			x	x				
	Neutralise							x													
	Influence sweeping																				
	Mechanical sweeping																				
	Jamming																				
DC 69 - Hydrografie	Collect			x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x
DC 74 - Naval Co-operation	Track/monitor																				
DC 84 - Search and Rescue	Transit																				
above water	Search																				
	Detect																				
	Identify																				
	Recover																				
	Salvage																				
Under water	Transit																				
	Search																				
	Detect																				
	Identify																				
	Recover																				
	Salvage																				

		Underwater Autonomous Combat AMPS	EMATT/ SUBMATT	Underwater Autonomous Reconnaissance ARCS	AUSS	Autosub -1	BPAUV	Cetus II	DeepC	Flying Plug	Gavia AUV	Hugin 1000	Hugin 3000	M600/ SeaOtter	Redermor AUV	REMUS AUV	SAHRV	SAUV	Sea horse	Theseus	Waya mba
DC 85 - Sea Surveillance	Patrol																				
	Search																				
	Detect																				
	Localise																				
	Classify																				
	Recognise																				
	Identify																				
	Track/monitor																				
	Interrogate																				
	Intercept																				
	Act/Engage/ Intervene																				
	Assess																				
	Apprehend																				
	Revisit																				
DC 87 - COMINT	Collect COMINT																				

In the following table the relevant capabilities of the Royal Netherlands Navy are linked to the Remotely Operated UUVs described in Chapter 3.

		Underwater Remotely Operated Combat		Underwater Remotely Operated Reconnaissance			Underwater Remotely Operated Rescue		
		Manta	PAP Mark 5	Double Eagle	SSUS	SubROV	Deep Drone-8000	Priz	Super Scorpio
DC 13 - Air Surveillance	Patrol								
	Detect								
	Localise								
	Classify								
	Recognise								
	Identify								
	Track/monitor								
DC 22 - ASW	Search								
(snorting submarine)	Detect								
	Localise								
	Classify	x							
	Act/Engage	x							
	Track/monitor								
	Assess								
(submerged submarine)	Search	x							
	Detect	x							
	Localise	x							
	Classify	x				x			
	Act/Engage	x							
	Track/monitor	x							
	Assess	x							
DC 23 - ASuW	Patrol								
	Search								
	Detect								
	Localise								
	Classify								
	Recognise	x							
	Identify	x							
	Track/monitor								
	Interrogate								
	Intercept								
	Act/Engage/Intervene	x							
	Assess	x							
	Apprehend								
	Revisit								
DC 47 - ELINT	Collect INTEL	x							
DC 54 - Border Patrol	Patrol								
(above water)	Detect								
	Localise								
	Classify								
	Recognise	x							
	Identify	x							
	Interrogate								

		Underwater Remotely Operated Combat		Underwater Remotely Operated Reconnaissance			Underwater Remotely Operated Rescue		
		Manta	PAP Mark 5	Double Eagle	SSUS	SubROV	Deep Drone-8000	Priz	Super Scorpio
DC 54 - Border Patrol (above water)									
	Intercept								
	Act/Engage/Intervene	x							
	Assess	x							
	Apprehend								
DC 57 - Harbour defence	Patrol								
(diver)	Search								
	Detect								
	Act/Engage/Intervene								
(IED)	Search		x	x	x	x	x		x
	Detect		x	x	x	x	x		x
	Investigate		x	x	x	x	x		x
	Remove			x	x		x		x
	Deactivate								
(Above water object)	Patrol								
	Search								
	Detect								
	Localise								
	Recognise	x							
	Identify	x							
	Track/monitor								
	Interrogate								
	Intercept								
	Act/Engage/Intervene	x							
	Assess	x							
	Apprehend								
	Revisit								
DC 62 - Coast guard	Patrol								
	Search								
	Detect								
	Localise								
	Classify								
	Recognise	x							
	Identify	x							
	Track/monitor								
	Interrogate								
	Intercept								
	Act/Engage/Intervene	x							
	Assess	x							
	Apprehend								
	Revisit								

		Underwater Remotely Operated Combat		Underwater Remotely Operated Reconnaissance			Underwater Remotely Operated Rescue		
		Manta	PAP Mark 5	Double Eagle	SSUS	SubROV	Deep Drone-8000	Priz	Super Scorpio
DC 65 - MMCM	Detect			x			?		
	Localise			x		?	x		
	Classify			x		x	?		
	Identify		x	x	x	x	x		
	Neutralise		x	x					
	Influence sweeping								
	Mechanical sweeping								
	Jamming								
DC 69 - Hydrografie	Collect			x	x				
DC 74 - Naval Co-operation	Track/monitor								
DC 84 - Search and Rescue	Transit								
above water	Search								
	Detect								
	Identify								
	Recover								
	Salvage								
Under water	Transit								
	Search	x							
	Detect	x					x		
	Identify						x		
	Recover								
	Salvage						x		
DC 85 - Sea Surveillance	Patrol								
	Search								
	Detect								
	Localise								
	Classify								
	Recognise	x							
	Identify	x							
	Track/monitor								
	Interrogate								
	Intercept								
	Act/Engage/Intervene	x							
	Assess	x							
	Apprehend								
	Revisit								
DC 87 - COMINT	Collect COMINT	x							

7.3 Linking capabilities to USSVs

In the following table the relevant capabilities of the Royal Netherlands Navy are linked to the USSVs described in Chapter 4.

		Semi-submersible Autonomous Reconnaissance		Semi-submersible Remotely Operated Reconnaissance		
		Basil	SASS 6M	AN/WLD-1 RMS	DOLPHIN	Dorado
DC 13 - Air Surveillance	Patrol					
	Detect					
	Localise					
	Classify					
	Recognise					
	Identify					
	Track/monitor					
DC 22 - SW	Search					
(snorting submarine)	Detect					
	Localise					
	Classify					
	Act/Engage					
	Track/monitor					
	Assess					
	Disseminate					
(submerged submarine)	Search	x	x			x
	Detect	x	x			x
	Localise	x	x			x
	Classify					
	Act/Engage					
	Track/monitor					
	Assess					
	Disseminate					

		Semi-submersible Autonomous Reconnaissance		Semi-submersible Remotely Operated Reconnaissance		
		Basil	SASS 6M	AN/WLD-1 RMS	DOLPHIN	Dorado
DC 23 - ASuW	Patrol					
	Search	x	x			
	Detect	x	x			
	Localise	x	x			
	Classify	x	x			
	Recognise	x	x			
	Identify	x	x			
	Track/monitor					
	Interrogate					
	Intercept					
	Act/Engage/ Intervene					
	Assess					
	Apprehend					
	Disseminate					
	Revisit					
DC 47 - ELINT	Collect INTEL					
DC 54 - Border Patrol	Patrol					
(above water)	Detect	x	x			
	Localise	x	x			
	Classify	x	x			
	Recognise	x	x			
	Identify	x	x			
	Interrogate					
	Intercept					
	Act/Engage/ Intervene					
	Assess					
	Apprehend					
	Disseminate					
DC 57 - Harbour defence	Patrol	x	x	x	x	x
(diver)	Search	x	x	x	x	x
	Detect	x	x	x	x	x
	Act/Engage/ Intervene					
(IED)	Search					
	Detect					
	Investigate					
	Remove					
	Deactivating					

		Semi-submersible Autonomous Reconnaissance		Semi-submersible Remotely Operated Reconnaissance		
		Basil	SASS 6M	AN/WLD-1 RMS	DOLPHIN	Dorado
DC 57 - Harbour defence	Patrol					
(Above water object)	Search					
	Detect					
	Localise					
	Recognise					
	Identify					
	Track/monitor					
	Interrogate					
	Intercept					
	Act/Engage/ Intervene					
	Assess					
	Apprehend					
	Disseminate					
	Revisit					
DC 62 - Coast guard	Patrol					
	Search	x	x			
	Detect	x	x			
	Localise	x	x			
	Classify	x	x			
	Recognise	x	x			
	Identify	x	x			
	Track/monitor					
	Interrogate					
	Intercept					
	Act/Engage/ Intervene					
	Assess					
	Apprehend					
	Disseminate					
	Revisit					
DC 65 - MMCM	Detect	x	x	x	x	x
	Localise	x	x	x	x	x
	Classify	x	x	x	x	x
	Identify			x		
	Neutralise					
	Influence sweeping					
	Mechanical sweeping					
	Jamming					

		Semi-submersible Autonomous Reconnaissance		Semi-submersible Remotely Operated Reconnaissance		
		Basil	SASS 6M	AN/WLD-1 RMS	DOLPHIN	Dorado
DC 69 - Hydrografie	Collect				x	
	Analyse					
DC 74 - Naval Co-operation	Track/monitor	x	x			
	Advise					
DC 84 - Search and Rescue	Transit					
Above water	Search					
	Detect					
	Identify					
	Recover					
	Salvage					
Under water	Transit					
	Search					
	Detect					
	Identify					
	Recover					
	Salvage					
DC 85 - Sea Surveillance	Patrol					
	Search	x	x			
	Detect	x	x			
	Localise	x	x			
	Classify	x	x			
	Recognise	x	x			
	Identify	x	x			
	Track/monitor					
	Interrogate					
	Intercept					
	Act/Engage/ Intervene					
	Assess					
	Apprehend					
	Disseminate					
	Revisit					
DC 87 - COMINT	Collect COMINT					
	Analyse COMINT					

7.4 Linking capabilities to USVs

In the following table the relevant capabilities of the Royal Netherlands Navy are linked to the USVs described in Chapter 5.

		Surface Autonomous Combat	Surface Remote Combat					Surface Remote Recce	
		Stingray USV	Protector USV	SAM III	SeaStar USV	Spartan Scout	Troika	Owl Mark II	Robo-ski
DC 13 -									
Air Surveillance	Patrol								
	Detect								
	Localise								
	Classify								
	Recognise								
	Identify								
	Track/monitor								
DC 22 – ASW	Search								
(snorting submarine)	Detect								
	Localise								
	Classify								
	Act/Engage								
	Track/monitor								
	Assess								
(submerged submarine)	Search					x		x	
	Detect					x		x	
	Localise					x		x	
	Classify								
	Act/Engage								
	Track/monitor					?		?	
	Assess								
DC 23 – AsuW	Patrol	x	x		x	x		x	x
	Search	x	x		x	x		x	x
	Detect	x	x		x	x		x	x
	Localise	x	x		x	x		x	x
	Classify	x	x		x	x		x	x
	Recognise	x	x		x	x		x	x
	Identify	x	x		x	x		x	x
	Track/monitor	x	x		x	x		x	x
	Interrogate		x		?	?			
	Intercept		x		x	x			
	Act/Engage/ Intervene		x		x	x			
	Assess	x	x		x	x		x	x
	Apprehend								
	Revisit								

		Surface Autonomous Combat	Surface Remote Combat					Surface Remote Recce	
		Stingray USV	Protector USV	SAM III	SeaStar USV	Spartan Scout	Troika	Owl Mark II	Robo-ski
DC 47 - ELINT	Collect INTEL	x	x		x	x			
DC 54 - Border Patrol	Patrol	x	x		x	x		x	x
(above water)	Detect	x	x		x	x		x	x
	Localise	x	x		x	x		x	x
	Classify	x	x		x	x		x	x
	Recognise	x	x		x	x		x	x
	Identify	x	x		x	x		x	x
	Interrogate		x		?	?			
	Intercept		x		x	x			
	Act/Engage/ Intervene		x		x	x			
	Assess	x	x		x	x		x	x
	Apprehend								
DC 57 - Harbour defence	Patrol				x				
(diver)	Search				x				
	Detect				x				
	Act/Engage/ Intervene								
(IED)	Search								
	Detect								
	Investigate								
	Remove								
	Deactivating								
(Above water object)	Patrol	x	x		x	x		x	x
	Search	x	x		x	x		x	x
	Detect	x	x		x	x		x	x
	Localise	x	x		x	x		x	x
	Recognise	x	x		x	x		x	x
	Identify	x	x		x	x		x	x
	Track/monitor	x	x		x	x		x	x
	Interrogate		x		?	?			
	Intercept		x		x	x			
	Act/Engage/ Intervene		x		x	x			
	Assess	x	x		x	x		x	x
	Apprehend								
	Revisit								

		Surface Autonomous Combat	Surface Remote Combat					Surface Remote Recce	
		Stingray USV	Protector USV	SAM III	SeaStar USV	Spartan Scout	Troika	Owl Mark II	Robo-ski
DC 62 - Coast guard	Patrol	x	x		x	x		x	x
	Search	x	x		x	x		x	x
	Detect	x	x		x	x		x	x
	Localise	x	x		x	x		x	x
	Classify	x	x		x	x		x	x
	Recognise	x	x		x	x		x	x
	Identify	x	x		x	x		x	x
	Track/monitor	x	x		x	x		x	x
	Interrogate		x		?	?			
	Intercept		x		x	x			
	Act/Engage/ Intervene		x		x	x			
	Assess	x	x		x	x		x	x
	Apprehend								
	Revisit								
DC 65 - MMCM	Detect	?	x		?	x		x	
	Localise	?	x		?	x		x	
	Classify	?	x		?	x		x	
	Identify								
	Neutralise								
	Influence sweeping			x			x		
	Mechanical sweeping			?			x		
	Jamming			x			x		
DC 69 - Hydrografie	Collect								
DC 74 - Naval Co-operation	Track/monitor	x	x		x	x		x	x
DC 84 - Search and Rescue	Transit	x	x		x	x		x	x
Above water	Search	x	x		x	x		x	?
	Detect	x	x		x	x		x	?
	Identify	x	x		x	x		x	?
	Recover								
	Salvage								
Under water	Transit								
	Search								
	Detect								
	Identify								
	Recover								
	Salvage								

		Surface Autonomous Combat	Surface Remote Combat					Surface Remote Recce	
		Stingray USV	Protector USV	SAM III	SeaStar USV	Spartan Scout	Troika	Owl Mark II	Robo-ski
DC 85 - Sea Surveillance	Patrol	x	x		x	x		x	x
	Search	x	x		x	x		x	x
	Detect	x	x		x	x		x	x
	Localise	x	x		x	x		x	x
	Classify	x	x		x	x		x	x
	Recognise	x	x		x	x		x	x
	Identify	x	x		x	x		x	x
	Track/monitor	x	x		x	x		x	x
	Interrogate		x		?	?			
	Intercept		x		x	x			
	Act/Engage/ Intervene		x		x	x			
	Assess	x	x		x	x		x	x
	Apprehend								
	Revisit								
DC 87 - COMINT	Collect COMINT				x				

8 Conclusions and observations

In this chapter we add up all systems in a matrix and draw conclusions based on this matrix. Also, we will analyse which combinations of categories are likely to occur and which ones are not. We then mention some general conclusions that arose from the previous chapter.

8.1 Advantages and disadvantages of UUVs, USSVs and USVs

8.1.1 *UUVs*

Advantages UUVs:

- UUVs are capable of covert operations because they are more silent than regular manned submarines.
- Some UUVs are relatively lightweight and small so they can be easily transported and controlled.
- Besides military missions there are also numerous civil opportunities in which a UUV can be applied. For instance, bottom classification, laying of cables and several environmental tasks.

Disadvantages UUVs:

- Communication between UUVs themselves as well as contact with above water platforms is rather difficult because of lack of radio transmission.
- Most UUVs are fitted with electrical propulsion. The required batteries are large and heavy. These batteries have a large impact on the UUV design. Furthermore, the UUV's endurance is limited (in the order of hours) because of limited capacity of the batteries.
- Some UUVs are fitted with a fuel cell, which gives them a longer endurance. But fuel cells are complex systems that are difficult to maintain.

8.1.2 *USSVs*

Advantages USSVs:

- Naturally a USSV is multifunctional, that means, semi-submersibles can be used both underwater and above water and are thus applicable for numerous tasks.
- Communication between a USSV and a surface platform is always done by radio transmission and thus poses few problems. A USSV can therefore be applied as a relay for underwater systems and above water systems.
- USSVs are normally fitted with diesel propulsion, which is simple and gives them a very long endurance (days or even weeks).

Disadvantages USSVs:

- To date, USSVs have received neither the acceptance nor the attention that has been given to UUVs.
- The number of USSVs in existence or being developed is small compared with that of UUVs.

8.1.3 *USVs*

Advantages USVs:

- A USV is capable of long operations (possibly with a duration of several weeks) without refuel or human intervention.
- A USV has a large payload capacity so it may also be applied for functions beyond its scope. With this one can think of rescue operations or transportation missions.
- A USV is normally driven by diesel which is a rather simple and reliable source compared to for example fuel cells.
- Communication is possible by radio transmission as well. It can therefore be applied as a relay for underwater systems and frigates.
- There is a gradual shift from remotely operated USVs only to more (nearly) autonomous USVs.

Disadvantages USVs:

- To date, USVs have received neither the acceptance nor the attention that has been given to UUVs.
- The number of USVs in existence or being developed is small compared with that of UUVs.
- The range of the above water sensors of USVs is limited because these sensors are normally positioned quite close to the sea surface.

(Ref: http://www.nap.edu/books/0309096766/html/116.html)

8.2 General observations

The table below gives the numbers of UVs from Chapters 3, 4 and 5, categorized into location, control and function.

	Autonomous			Remotely Operated		
	combat	reconnaissance	rescue	combat	reconnaissance	rescue
underwater	2	18	0	2	3	3
semi-submersible	0	2	0	0	3	0
surface	1	0	0	5	2	0

The following conclusions can be drawn from this matrix:

- Firstly, the dominant UV in this matrix operates underwater, is autonomous and has a reconnaissance task. This is true in 18 of the 41 cases.
- Secondly, if a UV has as task rescue, then it operates underwater and it is remotely operated.
- If a UV has an active combat task, then it is likely to operate on the surface. Similarly, if its task is passive combat, then the location of the UV is likely to be underwater.

  Note that in passive combat a UV is more or less a training object, whereas in active combat a UV participates in a task force.

The survey also shows that certain countries develop certain types of UVs:

- Israel is mainly active in the field of USVs for active combat, see Protector, Seastar and Stingray.
- The US is active with all kinds of UUVs and USSVs.
- Several countries have developed their own AUV for reconnaissance.

8.3 Conclusions regarding the types of UVs

The study described in this report was mainly carried out by analysing the information available on the Internet. During the study we found that unmanned systems are a very popular subject at this moment. A lot of research and development effort is being spent on unmanned systems. Many universities, research institutes and companies are developing systems. Almost on a weekly basis new systems and system concepts appear on the Internet. Therefore, the current report is a snapshot of the developments. It gives an overview of the status in the summer of 2006.

For this research the list of Defence Tasks and Capabilities, developed by the Netherlands Ministry of Defence was taken as a starting point. In this document 91 joint defence capabilities are defined. In the current report first a selection was made to find the capabilities relevant for naval operations. This resulted in 13 Maritime Defence Capabilities. Because unmanned systems are (at present) not capable of carrying out a whole defence capability on their own, these capabilities had to be split into parts. These parts were called subcapabilities in this report.

In the previous chapter a matrix matching the unmanned systems to the subcapabilities was presented. This matrix gives an overview of the capabilities of all investigated unmanned systems. From this matrix we can conclude the following:

AUV perform well in:

- Harbour Defence against divers (DC 57): patrol - detect

Both AUV and ROUV perform well in:

- Harbour Defence against IED (DC 57): patrol/search - investigate
- Maritime MCM (DC 65): detect - identify
- Hydrography (DC 69) collect

ASSV perform well in:

- Naval Co-operation (DC 74) track/monitor

Both ASSV and ROSSV perform well in:

- Harbour Defence against divers (DC 57): patrol - detect
- Maritime MCM (DC 65): detect - classify

Both ASV and ROSV perform well in:

- ASW against submerged (!) submarine (DC 22): search - localise
- ASuW (DC 23): patrol – assess
- ELINT (DC 47) collect
- Border patrol (DC 54): patrol – assess
- Harbour defence against above water object (DC 57): patrol – assess
- Coast guard (DC 62): patrol – assess
- Maritime MCM (!) (DC 65): detect – classify

- Naval Co-operation (DC 74) track/monitor
- Search and Rescue (DC 84): transit – identify
- Sea surveillance (DC 85): patrol – assess

As can be seen from this overview, there is no unmanned system that can carry out a complete Defence Capability on its own, except for DC 47 (ELINT), 69 (Hydrography) and 74 (Naval Co-operation), because these DCs only consist of a single subcapability.

From this list we can see that all 13 Maritime Defence Capabilities can be (partly) carried out by unmanned systems, except for DC 13, Air Surveillance. All other Defence Capabilities are at least partly covered by one or more unmanned systems.
Another interesting exception is DC 22, ASW against a snorting submarine. Only the Manta system (ROUV) is believed to have a capability against snorting submarines. Other systems are not believed to be able to discern the small above water targets presented by a snorting submarine (masts).

Most unmanned systems (both autonomous and remotely operated) have many sensors to sense their environment. Manipulating the environment is however a different story. Generally, autonomous systems are not able to manipulate their environment (act, engage, recover, apprehend, etcetera): this is reserved to remotely operated systems.

Many of the investigated systems have similar capabilities. For instance, there are many systems capable of mapping the seafloor and carrying out other hydrographic tasks. Apparently many research efforts are aimed at the same areas. This means that there is a lot of overlap between the systems.

However, at the same time there are some subcapabilities that no system can carry out at this moment. For instance: no systems were found that are capable to act against a diver (DC 57, Harbour defence).

Fortunately there are some developers that develop unique systems.
One example is Basil. Basil consists of a self-propelled intelligent GPS buoy with automated functionalities for dynamic positioning and programmed trajectory. It creates a sort of underwater GPS and is mainly used for positioning UUVs exploring oil fields.
Another remarkable system is the Flying Plug. The Flying Plug is a prototype underwater data connectivity device designed for deployment from submarines, aircraft and surface vessels. By using a system like Flying Plug, submarines may become part of network centric operations.
SubROV is also a very interesting system. It is small, highly manoeuvrable and is equipped with both color and low light cameras. The SubROV can be used to inspect both the submarine itself as well as the area surrounding it. This means that the SubROV is the only UUV (apart from the Manta system) that can be used to investigate (classifiy, identify) enemy submarines.

In some cases it was difficult to match a system to the subcapabilities, because they are general platforms that can be fitted with different sensors and systems. Examples are: Double Eagle, Wayamba and Spartan Scout. In order to make the matrix we analysed the applications of such platforms that already exist or are discussed in literature.

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10 Signature

The Hague, July 2007

TNO, Defence, Security and Safety

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Author

A The task and capability of the Royal Netherlands Navy

DC13 Air Surveillance Capability
Het systematisch observeren van het luchtruim met visuele, elektronische en andere middelen om bewegingen van vliegtuigen en raketten te volgen en te identificeren.

DC17 Algemene militaire capaciteit
Deze capaciteit is nodig ter ondersteuning van de regering in het algemeen en de eigen bewindslieden in het bijzonder. Hiervoor benodigde capaciteiten zijn strikt genomen geen operationeel vermogen, maar zijn onmisbaar voor de verantwoorde uitvoering van de andere taken. Onder algemene militaire capaciteiten wordt ook verstaan de internationale vertegenwoordiging.

DC18 Amphibious Assault Capability
Het vanuit zee plaatsen van eenheden op een (mogelijk) vijandelijke kust.

DC19 Amphibious Debarkation/embarkment Capability
Het vanuit zee op de kust afzetten of halen van personen en/of goederen.

DC20 Amphibious Raid Capability
Het vanuit zee plaatsen van eenheden op een (mogelijk) vijandelijke kust, met het oogmerk een korte actie uit te voeren waarna wordt teruggetrokken.

DC21 Amphibious Reconnaisance Capability
Het vanuit zee op het land plaatsen van een kleine eenheid voor het, doorgaans, heimelijk vergaren van informatie.

DC22 Anti-Submarine Warfare
Het opsporen van en optreden tegen onderzeeboten.

DC23 Anti-Surface Warfare Capability
Het opsporen en optreden tegen aan de oppervlakte varende schepen op zee.

DC28 Battle Damage Assessment Capability
Het waarnemen en beoordelen van de schade die is toegebracht door een militaire actie.

DC29 Battle Damage Repair Capability
Het, al dan niet geïmproviseerd, herstellen en operationeel (tijdelijk) bruikbaar maken van een faciliteit, vaak onder gevechtsomstandigheden.

DC31 Battlefield Surveillance Capability
Systematische waarneming met sensoren ter land, op zee en vanuit de lucht om over tijdige en accurate inlichtingen te beschikken

DC32 Boarding Capability
Het al dan niet met (expliciete) toestemming aan boord gaan.

DC33 Civil-Military Cooperation Capability
De coördinatie en samenwerking tussen militaire en overheids- en niet overheids organisaties en met de lokale bevolking, ter ondersteuning van een operatie.

DC37 Combat Search and Rescue Capability
Gewapend optreden door speciaal hiertoe getrainde eenheden gericht op het opsporen, identificeren en ophalen van kleine aantallen eigen personeel uit vijandelijk gebied.

DC38 Counterbattery Fire Capability
Vuur uitbrengen tegen vijandelijke vuursteunmiddelen, waarvan de locatie wordt vastgesteld aan de hand van eerder daardoor uitgebracht vuur.

DC39 Counter-guerilla Warfare Capability
Het vermogen irregulier optredende eenheden te bevechten. Hieronder wordt ook 'contraterreur' begrepen.

DC41 De- and Embarkation Capability
Het in- en uitladen van troepen en materieel dat van elders is aangevoerd.

DC42 Defensive Counter Air Capability
Luchtoptreden tegen offensieve en defensieve middelen van de tegenstander met het doel om eigen luchtoverwicht te verkrijgen of te behouden.

DC44 Disarmament, Demobilization and Re-integration Capability
Activiteiten van Defensiepersoneel om een (voormalig) conflictgebied te helpen de eigen veiligheidsorganisaties opnieuw in te richten.

DC45 Disaster Relief Capability
Militaire activiteiten gericht op het beperken van de gevolgen van een ramp en het bieden van hulp aan slachtoffers.

DC47 Electronic Intelligence Capability
Inlichtingenvergaring uit het elektromagnetisch spectrum.

DC48 Escort Capability
Operaties waarbij middelen worden ingezet ter begeleiding en bescherming van belangrijke personen, middelen en/of goederen (civiel en/of militair).

DC49 Evacuation Capability
Het elders in veiligheid brengen van personen die in dreigende omstandigheden verkeren.

DC50 Extended Air Defence
Luchtverdediging met conventionele middelen tegen de totale dreiging vanuit de lucht (inbegrepen ballistische raketten).

DC51 Fire Support Capability
Het leveren van vuursteun door land en/of maritieme eenheden, nauw afgestemd op het optreden van de eigen eenheden.

DC54 Grensbewakingscapaciteit
Uitvoeren van bij wet aan Defensie opgedragen activiteiten ter bewaking van de grenzen.

DC57 Harbour Defence Capability
Verdediging van een haven of ankerplaats en de toegang daartoe tegen externe dreigingen onder of op het water. Dreigingen vanuit de lucht worden gerekend tot de Air Defence.

DC58 Human Intelligence Capability
Inlichtingenvergaring via menselijke bronnen.

DC59 Information Operations Capability
Capaciteit om informatie en informatiesystemen te kunnen beïnvloeden met als doel om zowel het mensgerichte als het geautomatiseerde deel van het besluitvormingsproces van de opponenten doelgericht te beïnvloeden terwijl tegelijkertijd de eigen informatie en informatiesystemen worden beschermd.

DC60 Interpreter Capability
De capaciteit aan tolk-vertalers om te communiceren in andere talen.

DC61 Joint Mobile C4I Capability
De capaciteit om leiding te geven aan een operatie met eenheden van meerdere krijgsmacht(del)en.

DC62 Kustwacht Capaciteit
Het op en boven het water houden van toezicht op de territoriale wateren, en indien nodig daarbuiten, als bijdrage aan de handhaving van de rechtsorde door de civiele autoriteiten.

DC65 Maritime Mine Counter Measures Capability
Maritieme mijnenbestrijding om het effect van zeemijnen te voorkomen.

DC66 Medical Support Capability
Het bieden van medische assistentie met militaire middelen aan andere eenheden en/of burgers. Indien het gaat om de organieke medische ondersteuning van een eenheid, wordt dit niet gezien als een separate militaire capaciteit.

DC67 Medical Evacuation Capability
Het naar elders brengen van patiënten die tijdens de evacuatie medische begeleiding en/of zorg behoeven.

DC68 Military Geografic Information Capability
Het verzamelen en analyseren van geografische gegevens voor militaire doeleinden.

DC69 (Military) Hydrographic Information Capability
Het verzamelen en analyseren van geografische gegevens over zeegebieden.

DC74 Naval Co-operation and Guidance for Shipping
Het monitoren en adviseren van bewegingen van civiele schepen.

DC75 Nuclear Biological, Chemical Defence Capability
Maatregelen gericht op de verdediging tegen aanvallen en incidenten met nucleaire, biologische en chemische middelen en de gevolgen daarvan.

DC78 Operational Intelligence Capability
De capaciteit om grond/lucht en zeegebonden inlichtingen-verzamelsystemen (zowel fysiek als elektronisch) en overige informatiebronnen door middel van een gecoördineerde inzet, adequate verwerking en uitgebreide analyse onafgebroken te laten voldoen aan de informatiebehoefte van de operationele commandant

DC81 Sea Basing Capabilities
Het gebruik van de zee als onafhankelijke basis voor het uitvoeren van operaties op het land en de ondersteuning daarvan.

DC82 Sea Control Capability
Optreden gericht op het waarborgen van de eigen bewegingsvrijheid, onder, op en boven water, in een bepaald gebied.

DC83 Sea Denial Capability
Het ontzeggen van de bewegingsvrijheid op zee aan de tegenstander, zonder dat het betrokken zeegebied dermate wordt beheerst dat aldaar de bewegingsvrijheid van de eigen eenheden is gewaarborgd.

DC84 Search and Rescue Capability
Het gebruik van militaire middelen om personeel uit dreigende of nood-omstandigheden te halen.

DC85 Sea Surveillance Capability
Het systematisch waarnemen van een zeegebied met het doel maritieme bewegingen op en onder water te lokaliseren, te identificeren en te volgen.

DC86 Sea-to-Sea Re-supply and Re-fuelling Capability
Het herbevoorraden en bijtanken van schepen op zee.

DC87 Signal Intelligence Capability
Inlichtingenvergaring uit communicatieverbindingen van derden.

DC88 Special Operations Capability
Het, doorgaans heimelijk, autonoom en in kleinere verbanden, ter plaatse verkennen, overmeesteren of uitschakelen van een doel onder moeilijke omstandigheden.

DC90 Strategic Strike Capability
Het vermogen tot op grote afstand belangrijke doelen van een tegenstander uit te schakelen.

DC91 Strategic Transport Capability
Het verplaatsen van personeel en/of goederen over zee, door de lucht of over land over grotere afstanden tot en met andere continenten, waarna de eenheid eerst ter plaatse wordt samengesteld en operationeel inzetbaar gemaakt

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15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

The introduction of unmanned vehicles may have serious consequences for naval operations. Therefore, in the future the Royal Netherlands Navy needs to have sufficient knowledge to be able to make sound decisions with respect to procurement and employment of such vehicles. In an earlier study research had already been carried out into unmanned aerial vehicles. In this project it was examined which defence capabilities can be carried out with unmanned surface and underwater vehicles. First an inventory of current and future unmanned vehicles and a subdivision into three categories were made. Next it was tried to project the listed vehicles on the capability list of the Royal Netherlands Navy. This appeared to be difficult, because for this study the capabilities were not detailed enough. Therefore, these capabilities were further subdivided into 'subcapabilities', so next the suitability of the listed vehicles for those subcapabilities could be investigated.

16. DESCRIPTORS	IDENTIFIERS
unmanned vehicles, task performance, navy	underwater, semi-submersible, surface, remotely operated, autonomous, reconnaissance, combat, rescue defence capabilities

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