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D 6.1.2. Evaluation of safe technology

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Dissemination level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

1 INTRODUCTION

1.1 Scope of Work

This report documents the first observations of the periodic evaluation of safe technology. The primary aim of this deliverable is to provide initial design guidelines for ensuring diver safety by building a regulatory framework for the acceptance of robotics in the diver community. During this first period, the existing vehicles that will be adapted for the purposes of the CADDY project are evaluated regarding safety issues. This task will be active during the rest of the CADDY project.

1.2 Liability Disclaimer

The analysis compiled in this report are prepared for the vehicle list provided by the project partners, and cannot be used as a general guideline for other submersible AUV's or Robot operations. This initial analysis is based on the design documents provided by the partners and they are NOT yet validated during open water functionality tests.

2 FORMAL RISK ASSESMENT on EXISTING VEHICLES

2.1 Background

The risk assessment is performed based on the quantification described at deliverable 6.1.1 page 12 using the hazards of man-machine interaction described in the section 2.2 of the deliverable 6.1.1. namely:

a. Trauma
b. Electrical shock
c. Acoustical trauma
d. EM hazards

2.2 Risk assessment on Trauma

Vehicle/Device	Probability	Exposure	Consequence	Score	Risk
Muddy Waters II (AUV)	3	5	1	15	Medium
SeaMor 300F - ROV	3	5	4	60	Very High
PlaDyPos	1	3	2	6	Medium
Buddy - AUV	3	5	4	60	Very High
Charlie USV	1	3	4	12	Medium
e-URoPe ROV/AUV	3	5	2	30	High
Delfim	1	3	5	15	Medium
DelfimX	1	3	5	15	Medium
MEDUSA-S	1	3	3	9	Medium
MEDUSA-D	3	5	3	45	High

For Surface vehicles the probability of "unlikely" (Grade 1) since collision may only occur before or after diving especially during an unexpected emergency ascent swimming; Whereas, for AUV's it is "possible" (Grade 3) during validation trials. The observed probability should be as low as Zero during the sea trials for every type of vehicle.

For Surface vehicles the exposure is assumed to be at the level of "occasional" when compared to workplace equivalents once per week (Grade 3); Whereas, for AUV's it is continuous (Grade 5).

The consequence of the trauma is a function of the number of propeller, power of each propeller and the momentum of each vehicle computed at maximum velocity and the form factor of the vehicle. (See Table below). Maximum impact is assigned to be catastrophic (Grade 5) and the minimum is noticeable and requires first aid (Grade 1). The other grades are interpolated accordingly.

2.3 Collision impact of each vehicle

Vehicle/Device	#of propeller	Power (watt)	Weight (kg)	Max Speed (knots)	Form f	Impact	Consequence
Muddy Waters II (AUV)	2	100	14	1	3	8400	1
SeaMor 300F - ROV	2	150	35	2	2	231.000	3
PlaDyPos	4	100	30	2	1	24.000	2
Buddy - AUV	4	150	40	3	3	216.000	3
Charlie USV	2	300	300	1	5	900.000	4
R2	4	120	70	0,5	3	50.400	2
Delfim	2	1100	300	5	5	16.500.000	5
DelfimX	2	1000	350	5	5	17.500.000	5
MEDUSA-S	2	200	23	3	5	138.000	3
MEDUSA-D	2	200	30	3	5	180.000	3

2.4 Risk assessment on Electrical Shock

Vehicle/Device	Probability	Exposure	Consequence	Score	Remarks
Muddy Waters II (AUV)	1	5	2	10	Medium
SeaMor 300F - ROV	1	3	2	6	Medium
PlaDyPos	1	5	2	10	Medium
Buddy - AUV	1	3	2	6	Medium
Charlie USV	1	5	2	10	Medium
e-URoPe ROV/AUV	1	3	2	6	Medium
Delfim	1	3	3	9	Medium
DelfimX	1	3	3	9	Medium
MEDUSA-S	1	5	2	10	Medium
MEDUSA-D	1	5	2	10	Medium

For all vehicles it is unlikely to have an electrical shock (Probability Grade 1).

For Surface vehicles the exposure is assumed to be at the level of "occasional" when compared to workplace equivalents once per week (Grade 3); Whereas, for AUV's it is continuous (Grade 5).

The consequence is assumed to be significant (Grade 2) for the devices working with several hundreds of Watt but is serious for vehicles above 1 kW (Grade 3).

2.5 Risk assessment on Acoustical Trauma

Vehicle/Device	Probability	Exposure	Consequence	Score	Remarks
Muddy Waters II (AUV)	1	5	1	5	Acceptable
SeaMor 300F - ROV	1	5	1	5	Acceptable
PlaDyPos	1	5	1	5	Acceptable
Buddy - AUV	1	5	1	5	Acceptable
Charlie USV	1	5	1	5	Acceptable
e-URoPe ROV/AUV	1	5	1	5	Acceptable
Delfim	1	5	1	5	Acceptable
DelfimX	1	5	1	5	Acceptable
MEDUSA-S	1	5	1	5	Acceptable
MEDUSA-D	1	5	1	5	Acceptable

Note that the probability is taken as the probability of being subjected to a trauma causing acoustical emission (unlikely).

2.6 Risk assessment on EM Hazards

Vehicle/Device	Probability	Exposure	Consequence	Score	Remarks
Muddy Waters II (AUV)	1	5	1	5	Acceptable
SeaMor 300F - ROV	1	3	1	3	Acceptable
PlaDyPos	1	5	1	5	Acceptable
Buddy - AUV	1	3	1	3	Acceptable
Charlie USV	1	5	1	5	Acceptable
e-URoPe ROV/AUV	1	3	1	3	Acceptable
Delfim	1	3	1	3	Acceptable
DelfimX	1	3	1	3	Acceptable
MEDUSA-S	1	5	1	5	Acceptable
MEDUSA-D	1	5	1	5	Acceptable

3 IMPROVEMENTS on SAFETY

According to the above risk analysis the major risk is the trauma caused by the collision of the vehicle and the diver. The secondary risk is the electrical shock. The acoustical and EM risks are minor and are at acceptable level. The mechanical and electrical risks can be minimised by design, procedures and training.

3.1 Design

The electrical hazards can be minimised by compliance with the IMCA standards (IMCA D045 Code of practice for the safe use of electricity under water). It is suggested that the vehicles are inspected by a third party auditor against the IMCA standard. To restrict the collision impact of the vehicles, the propeller guards must be reinforce and the kill switch designs should be finalised.

On the other side, a protected redundant SCUBA will be used to protect the divers in case of emergencies. This system is developed by Innovasub; a company who is in the user board of CADDY in coordination with DAN Europe. The SCUBA system is enclosed in a carbon fibre tank to protect both the equipment and the back side of the diver (Figure 1). The system has dual redundant tank so in case of failure of one SCUBA the diver has a second tank with regulator and buoyancy control.

Figure 1 Protected Redundant Scuba System: NarmorX

Figure 2 The NarmorX during Sea Trials and the Custom NarmoX built for DAN Europe

On the other side, is decided to use through water communication system for high visibility dives and thereby full face masks to enable the communication. The company who is manufacturing the full face masks, OceanReef, also integrated the mask to a helmet in order to protect the head of the diver.

Figure 3 Full face mask with communications and the head protecting helmet

Integration of NarmorX to Ocean Reef full face mask and communication system required additional custom designs:

- The dual tanks are combined over the first stage of the breathing regulators via a custom built low pressure bridge. In case of the failure of the first breathing system the second system is in place automatically.
- In case of the failure of full face mask second stage, an additional 2nd stage is connected to the buoyancy compensator. This prevents entanglement of the additional second stage used for safety.

Figure 4 Dual tanks combined by the low pressure bridge (Picture on the left – yellow hose); all hoses are protected by the fiberglass case, spare regulator is attached to the BC hose (picture on the right yellow regulator).

3.2 Procedures

The efficiency of kill switches must be tested before putting the divers in the vicinity of the vehicles together with the electrical checks. These needs to be formalized under the "CADDY – Device checklists."

The new diving system has a different checklist then conventional SCUBA. It includes the checks for full face masks as well as the checks related to the use of the low pressure bridge (See on the next page). The procedure will be tested during the dives at Y40 on the 2nd and 3rd of February, 2015. Eleven divers who will be diving with CADDY system is selected among the very experienced divers at DAN Europe (more than 500 logged dives and at the level of dive leader or instructor).

3.3 Training

The dive team is named Alfa Team and started to be trained on the use of Full Face masks and the communication system in St Marguerita in September 2014. One of the divers is also certified as Full Face Mask Instructor in order to ensure the continuity of the training.

Figure 5 Training on the use of Full face Masks

The Alfa team will participate to the experiments in Y40 on the 2nd and 3rd of February, 2015. They will be practicing the efficient use of their dedicated system consisting of NarmorX, Full Face Masks and communication. Before diving with AUV's, Alfa team will get more familiarize with the AUV's; will start practicing emergency scenarios and will update their courses on advances first aid and rescue.

IN WATER PREDIVE CHECK LIST– FFM/NarmorX

Name of the diver									
Date									
SAV open/Tanks closed									
Helmet Secure									
R-Tank open read gauge Right									
L-Tank open read gauge Left									
SAV Closed Breath									
Tanks Closed Breath									
Primary tank R? Or L?									
Check ears									
Adjust regulator									
Depth gauge /DC									
BC									
Weight system									
Knife									
Fins									
SMB									
Pocket mask									
Light									
Spare Air									
Comms									
Safety Stop SCUBA									
Stand by ready									
Time in									
Time out									
SPG-L end of dive									
SPG-R end of dive									
Diving Master Inıtials									

DSO Name:
DSO Approval:
Diving Supervisor Name:
Diving Supervisor Approval: