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D 6.1.3. 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 results of the periodic evaluation of safe technology. The primary aim of this deliverable is to document the improvements for ensuring diver safety by building a regulatory framework for the acceptance of robotics in the diver community. The second period of activity covers the follow up of the first activity in T4.4 where initial experiments and performance evaluation of the complete robotic system take place.

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->4	1	15->12	Medium
SeaMor 300F - ROV	3	5->4	4->3	60->36	High
PlaDyPos	1	3->1	2->1	6->1	Low
Buddy - AUV	3->2	5->4	4->2->1	60->8	Medium
Charlie USV	1	3->1	4->3	12->3	Low
e-URoPe ROV/AUV	3	5->4	2->1	30->12	Medium
Delfim	1	3->1	5->4	15->4	Low
DelfimX	1	3->1	5->4	15->4	Low
MEDUSA-S	1	3->1	3->2	9->2	Low
MEDUSA-D	3	5->1	3->2	45->6	Medium

Several Risk Mitigation techniques were used for decreasing the Trauma risk. As a consequence the risk values in the parameters are shifted from the black values to green values.
The situation before the risk mitigation was as follows:

Design:
The design of the BUDDY vehicle is changed to add propeller guards; making the form factor safer. The speed of the vehicle is also to be reduced to maximum value of 1 knot. On the other side the weight of the vehicle reached 50 kg. So, the consequence grade dropped from 3 to 2. The use of the kill switches decreased the probability of an accident from 3 to 2.

Collision impact of each vehicle

Vehicle/Device	#of propeller	Power (watt)	Weight (kg)	Max Speed (knots)	Form f	Impact	Consequence
Muddy Waters II	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->50	3->1	3->1	30.000	3->2
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

Procedural change:
For Surface vehicles the exposure was assumed to be at the level of “occasional” when compared to workplace equivalents once per week (Grade 3); whereas, for AUV’s it was assumed to be continuous (Grade 5). There are several changes in the diving procedures that reduced the exposure to collision as well as the consequences significantly:

a/ The use of redundant protected SCUBA, well trained first response team, the use of continuous stand-by rescue diver and personal protection like Helmets the consequence of the collision from by 1 grade for all vehicles.

b/ The use of through water communication system with full face masks reduces the exposure to ASV to the minimum level 1; and decreases the AUV exposure by one grade since they permit warning the diver by communication. All procedural changes required training and exercises to rehearse the related skills.

2.3. Risk assessment on Electrical Shock

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

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 was 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). The suggestion to inspect the vehicles against the electrical hazard was made before the consortium knew what would be the power supply of our vehicles. IMCA D045 "Code of Practice for The Safe Use of Electricity Under Water" is long document analysing all possible situations when safety voltage is not used. When safety voltage is used only one statement is important: "Provided the voltage of any item that the diver may come in contact with is less than a ‘safe’ level then work may be carried out in safety". Voltage on all vehicles is safe voltage so the third party inspection is cancelled. Safe voltage levels are explained also in D.5.1. All electrical risks now conform to ALARP (As low as reasonably practicable).

2.4. Risk assessment on Acoustical Trauma and EM hazards

There are no changes in the risk assessment of the acoustical trauma and EM hazards and they are still at acceptable level for all vehicles as described in the previous deliverable (D.6.1.2).

3. IMPROVEMENTS on SAFETY

The suggestions on the improvements of safety are followed by the consortium; and the risks dropped to an acceptable level for almost all vehicles for all potential hazards.

According to the above risk analysis, there is one vehicle that is still on the high risk category for trauma (SeaMor 300F - ROV). It is suggested to avoid the use of this vehicle in the vicinity of divers unless the kill switches and propeller guards are installed.

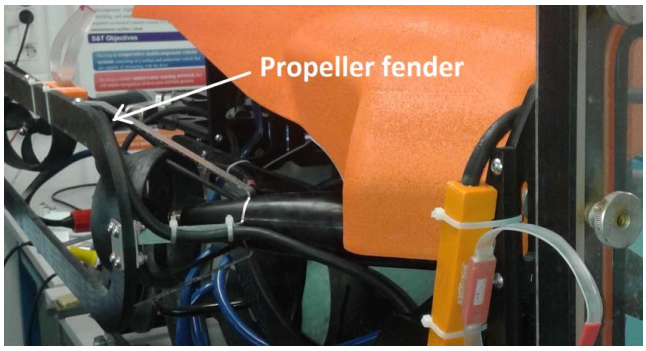
There are four vehicles that fall into medium risk category for trauma: BUDDY, Muddy Waters II (AUV), e-URoPe ROV/AUV and MEDUSA-D. Given the fact that BUDDY vehicle is the only vehicle operating in the close vicinity to divers, drops the risk to ALARP level for all tree vehicles. Unless further risk mitigation is applied, the only way to reduce the risk of trauma from BUDDY vehicle is to limit its speed to less than 0,5 knots.

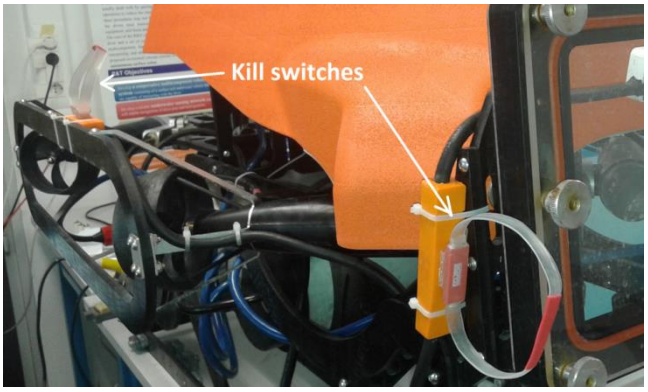
The efficiency of kill switches and electrical systems must be tested before putting the divers in the vicinity of the vehicles together with the electrical checks. This needs to be formalized under the “CADDY – Device checklists.” This final improvement is scheduled to be performed at the last year of the project. The safety checklist given in the annex must be filled/updated for all the vehicles prior to the open water dives.

ANNEX A. CADDY Safety Validation Questionnaire

The purpose of this questionnaire is to assess the safety of CADDY autonomous vehicles. Please indicate the vehicle compliance with each of the statements, by placing an **x** in the appropriate box. Fill out the comment tab where necessary.

Vehicle: BUDDY AUV (UNIZG-FER)

Index	Safety		yes	no	comment
1	Are the propellers of the AUV guarded in order to prevent injuries?		x		Propeller guard is not installed on the thruster itself but fender is installed instead to disable the direct access to the propellers (see image below). 
2	Do acoustic devices installed on the vehicle (modem, Sonar, Doppler velocity log) meet the safety requirements from the D6.1.1.	Modem	x		According to requirements from D.6.1.1.
		Sonar	x		According to requirements from D.6.1.1. Sonar ARIS posses acoustic emission test certificate and approved permit to monitor protected and endangered species in the USA according to manufacturer.
		DVL	x		According to requirements from D.6.1.1.
3	Sound source with the frequency close to the human lung resonant frequency of 42 Hz is not used.		x		Yes, means that low frequency sound source is not used.
4	RECUV power supply is in compliance with IMCA code of practice.		x		The vehicle power supply is 46.8V DC battery. It is equipped with tripping device with a reaction time of less then 20ms. Consequently it is considered electricaly safe according to criteria set in D.5.1, D6.1.1 and "Code of Practice for The Safe Use of Electricity Under Water", IMCA document D 045, R 015, October 2010.

5	Activation of the kill switch stops the operation of the vehicle immediately.	Sw.1	x		All mechanical kill switches are tested. Their activation stops the operation of the vehicle immediately. Haptic kill switch is not operational at this stage and it will be tested during the next trials.
		Sw.2	x		
		Sw.3	x		
		Sw.4	x		
		Sw.5	x		
		Haptic	N/A		
6	Position and number of kill switches ensure safe stopping of the vehicle from all sides.		x		The five switches are evenly distributed around the vehicle (forward-left, foreword-right, left, right, back). It satisfies criteria set in D5.1. and D.6.1.1.
7	It is quick, simple and obvious to operate kill switches even for panicking user.		N/A		To activate the kill switch it is enough to pull off the stripe/handle from the switch. Furthermore kill switches are coloured red and orange to make them visible and to make their function obvious. Due to limited number of AUV dives with the diver, further testing with more divers is required during the second validation trials.