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Western Norway
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MASTER'S THESIS

Studying/Exploring the issues towards automation of the LARS

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Program: Master in Maritime Operations

Department: Maritime Operations – (Code: MMO5017)

Intern Supervisor: Ajit Kumar Verma

15th of September, 2020

Preface

This thesis has been the final work in a master's degree in Maritime Operations at the Western Norway University of Applied Sciences and is credited 30 ETC points.

Ajit Kumar Verma is the leading figures on the team from Western Norway University of Applied Sciences. This investigation has been carried out with a great cooperation of a company Deep Ocean AS, that have a huge knowledge on offshore tasks, and it vessels and systems, like the LARS. In addition, has been completely indispensable to make use of the literature search review.

Acknowledgements

I own a great deal of thank-you´s and appreciations to my internal supervisor, Ajit Kurma Verma. He is a great teacher, researcher and research guide. Totally is a role model for his students and research scholars – thank you!

Also, I would like to thank to my extern supervisor Jone Vikingstad for guiding my in the visiting on board of vessel EDDA FAUNA, and with some technical and ingeniering aspects – thank you!

In addition, some members of the company DeepOcean owes a lot of appreciation to help got. Andries Ferla have guided me in the beginning of the project when I was complettely lost. He halp me to find the way, and the enginner Jostein Røed who is the person which most have contributed to help me and clarify me all concerning LARS that I did not known– thank you to both of you too!

Summary

Autonomous vessels and its subsea operations are not merely one of many sides of technological progress, but it will be also an innovation that disrupts and induces a paradigm shift in the ship industry as a whole.

Recently, advances in technology spanning digitalization, big data and Artificial Intelligence (AI) have reached a level where commercialization of autonomous ships are imminent, and the development of technology of these kinds of vessels and all around them has been progressing at a rapid pace.

In 2017, the International Maritime Organization (IMO) decided to adopt as one of its seven Strategic Directions to be pursued for the 2018-2023 timeframe, “Integrate new and advancing technologies in the regulatory framework” [1],[2].

In June 2018, it decided to embark on the Regulatory Scoping Exercise (RSE) to adopt and operate Maritime Autonomous Surface Ships (MASS) [1].

As a result, the global community has been called to make various efforts in technical and social aspects to accommodate autonomous vessels.

Concerning to the technical aspects of the LARS, there are some pre & post dive chekcs on th ROV nowadays which are mention in NORSOK (Norwegian shelf's competitive position) and IMCA (International Maritime Contractors Association) [3],[4].

This thesis will contribute in the exploration of what technical aspects, and social aspects in some way too, are needed to carry out the automated LARS of subsea vehicles. Described more specifically, the aim of this master thesis is to study and explore how could be possible to automate the LARS operation in moonpools.

The thesis has been conducted by literature studies and performing interviews to some crewmembers experienced in this operation in both, technical and practical aspects.

The objective of getting an automated LARS is to decrease the risk of human life on board. Consequently, the economic and safety environment would be greatly favoured too, being that it would happen less accident due to it will be more safety to equipment and personal, and also, because the operation would be faster carried out.

Studying the way to convert the LARS in an automated operation, it has been considered that this will change the situation of operators.

At the end of the thesis there is a selection of subjects for future researchers.

List of figures

Abbreviations

Abbreviation	Description
AHC	Active Heave Compensation
AI	Artificial Intelligence
CT	Constant Tension
DO	Deep Ocean ASA
EMC	Electro Magnetic Compatibility
HPU	Hydraulic Power Unit
Hs	Wave height
IMCA	International Maritime Contractors Association
IMO	International Maritime Organization
IMR	Inspection, Maintenance and Repair
LARS	Launch and Recovery
MASS	Maritime Autonomous Surface Ships
LAT	Latitude
NORSOK	Norwegian shelf's competitive position
MHS	Module Handling System
OBSROV	Observation ROV
PLC	Programmable Logic Controller
PTiL	Petroleum Safety Authority Norway
PTZ Camera	Pan-Tilt-Zoom Camera
RQ	Research Question

ROT	Remote Operated Tool
ROV	Remotely Operated Vehicle
RSE	Regulatory Scoping Exercise
S-O-A	State-of-the-Art
SWL	Safe Working Load
TMS	Tethered Management System
WROV	Work ROV

Table of contents

1. Introduction

The object of this chapter is to give the Research Question (RQ), naming methods used to answer the RQ. To then list, with a short description of each one, of chapters that it will be found further.

1.1. Research Question

The goal of this thesis is to study and explore the task of LARS of subsea vehicles, and the RQ is how convert the LARS task of subsea vehicles in an automated task.

To get this goal, it has been needed to be on board of a vessel with launch and recovery system, and then to investigate about what new items and technology is needed to get the above-mentioned objective. All this study has been firstly based on before investigations and facts already got by other investigators. But, methods will be described in more detail in the chapter 3.

1.2. Structure of the thesis

Chapter 1 Introduction.

> Description: A general and a very short summary of the thesis, through the research question and the structure of the thesis.

Chapter 2 Theoretical background.

> Description: Here the point is to give to readers technical knowledges about the different components of the system and about what consist the operation of LARS operation in moonpools of subsea vehicles (in this case of WROVs), to get understand in further chapters changes that it will proposed the exploring on how to convert this in an automated operation. It has been described the main characteristics of the visited/pilot vessel.

Chapter 3 Methodology.

> Description: A explanation of different scientific methods used for answering the research question and, followed, writing the thesis.

Chapter 4 Results and Discussions.

Description: This chapter will describe, between others, sub-systems, components and parameters found out in this study, and the way they could be used to get a desired automated LARS's operation. Discussions such results are involved in this chapter at the same time.

Chapter 5 Conclusion.

Description: The summary of the conclusions of more relevance of this thesis.

Chapter 6 Further work.

Description: This chapter will house the recommendations for further work found in this investigation.

2. Theoretical Background

In this chapter a lot of valid information was collected and described. What different types of LARS exists, subsystems and components of the LARS, the explanation on how it is carried out the whole operation nowadays, pictures taken by myself, and challenges to be done in the future, have been described in following chapters.

2.1. Boundedness

To frame this study, we have been forced to limit the environment, i.e., to narrow the area of investigation according to the surroundings to this operation. We avoid on this way that the investigation does not encompass several and different investigation areas, avoiding at the same time a huge extension of the work, but only taking focus on the LARS.

To know how could be possible of getting an automated LARS, we must understand first technic functions of the major parts of this system. EDDA FAUNA is the vessel where we have visited to get a better comprehension of LARS; it has been got doing interviews to some crewmembers, obtaining on this way, valid information for our investigation. So, due to our visit and investigation was based on LARS task of this vessel, we will take focus in LARS of moonpools.

I will provide technical information about the LARS based on this vessel. But not before give the main type of LARS and the characteristics of EDDA FAUNA.

2.2. Two main different LARS

In general, there are 2 different types of LARS: over the side and trough moonpools.

1. <u>Over the side</u>

Figure 1: Example of LARS over the side, Macgregor [5]

Delivering the highest of specifications. The Basic LARS for work-class ROVs is based on our high-end system. It uses the same high quality steel components and features such as docking head flexibility, dual tilted A-frame and gentle handling of umbilical are maintained.

Over side LARS use hydraulic or electric active heave-compensated umbilical winch for the safe launch and recovery of various types of ROVs.

LARS here can include componentslike a telescoping frame, winches, locks, hydraulic power unit (if needed) and a control system. The telescoping snubber can reduce motions. The compact, overhead, telescoping design of the LARS ensures safety.

Crew safety and comfort can be further enhanced by placing the side-hangar door tops below the LARS. This allows the hangar doors to be closed even when the ROV is launched. [5]

1. <u>Through moonpool</u>

Figure 2: LARS through moonpools, of vessel EDDA FAUNA.

Moonpool launch-and-recovery systems (LARS) are exceptionally reliable and precise, designed to withstand significant dynamic forces and operate in a wide weather window. Moonpool LARS are delivered with a vessel-integrated, rail-mounted guide cursor and a highly accurate hydraulic or electric winch, large screen-based control panel and moonpool door system. Cursor locks allow secure and convenient parking at heights ideally suited to maintenance operations or traffic around or under the ROV.

In the following chapter, it will be described the main characteristics of the vessel which has been based this investigation, as named above in Ch. (2.1. Boundaries); he explanation in more detail of components of LARS in moonpools; In the description of the operation, step by step.

2.3. Characteristics of vessel EDDA FAUNA

The vessel EDDA FAUNA is installed with a OBSROV with LARS over the side, and <u>2 WROV with a LARS in moonpools</u>, where is thesis will take focus on. The LARS consists of a cursor guided on 2 rails from the top of the ROV hangar to the bottom of the vessel moonpool.

Figure 3: Vessel EDDA FAUNA, in Haugesund.

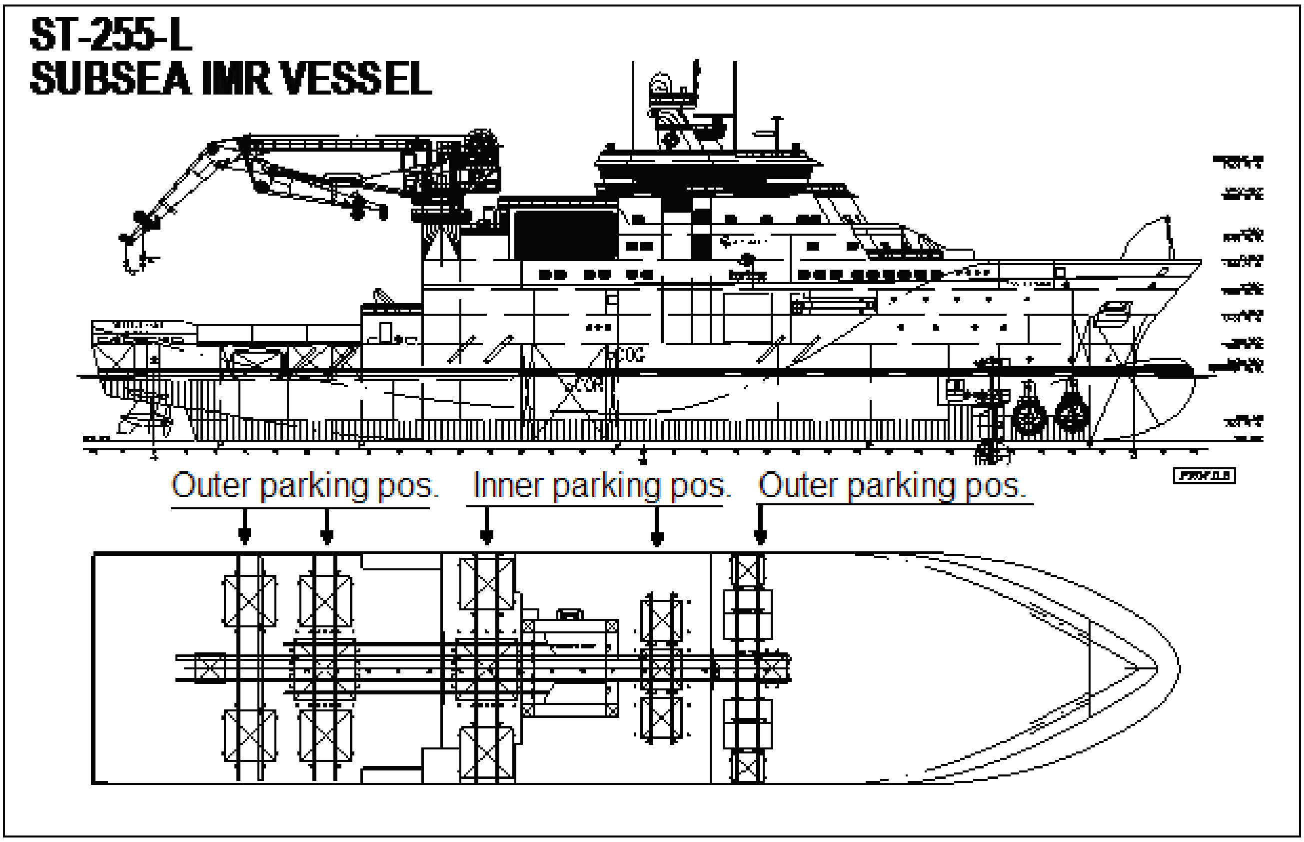


Figure 4: General arrangment of EDDA FAUNA.

Vessel specifications is given in the following table [6]:

Main characteristics	
Name	EDDA FAUNA
Call sign	JWMZ3
Flag	Norway [NO]
IMO no.	9368948
MMSI	259665000

Home port	Haugesund
Type	Subsea IMR and ROV support vessel
Build number	117
LOA	108,70 m
Draugth	7,80 m
Length	108 m
Breadth	23 m
Gross tonnage	9464 tons
Deadweight	6200 tons
Build year	2008
Accomodation	90 persons
Shipowner/Manager	Østensjø AS
Builder	Aker Yard Brattvaag
Construction material	Steel
Operating status	Active

Figure 5: Main characteristics of EDDA FAUNA

2.4. Subsystems and components of the LARS in moonpool

In this chapter, is given a detailed description of the WROV LARS and each of the main subsystems and components.

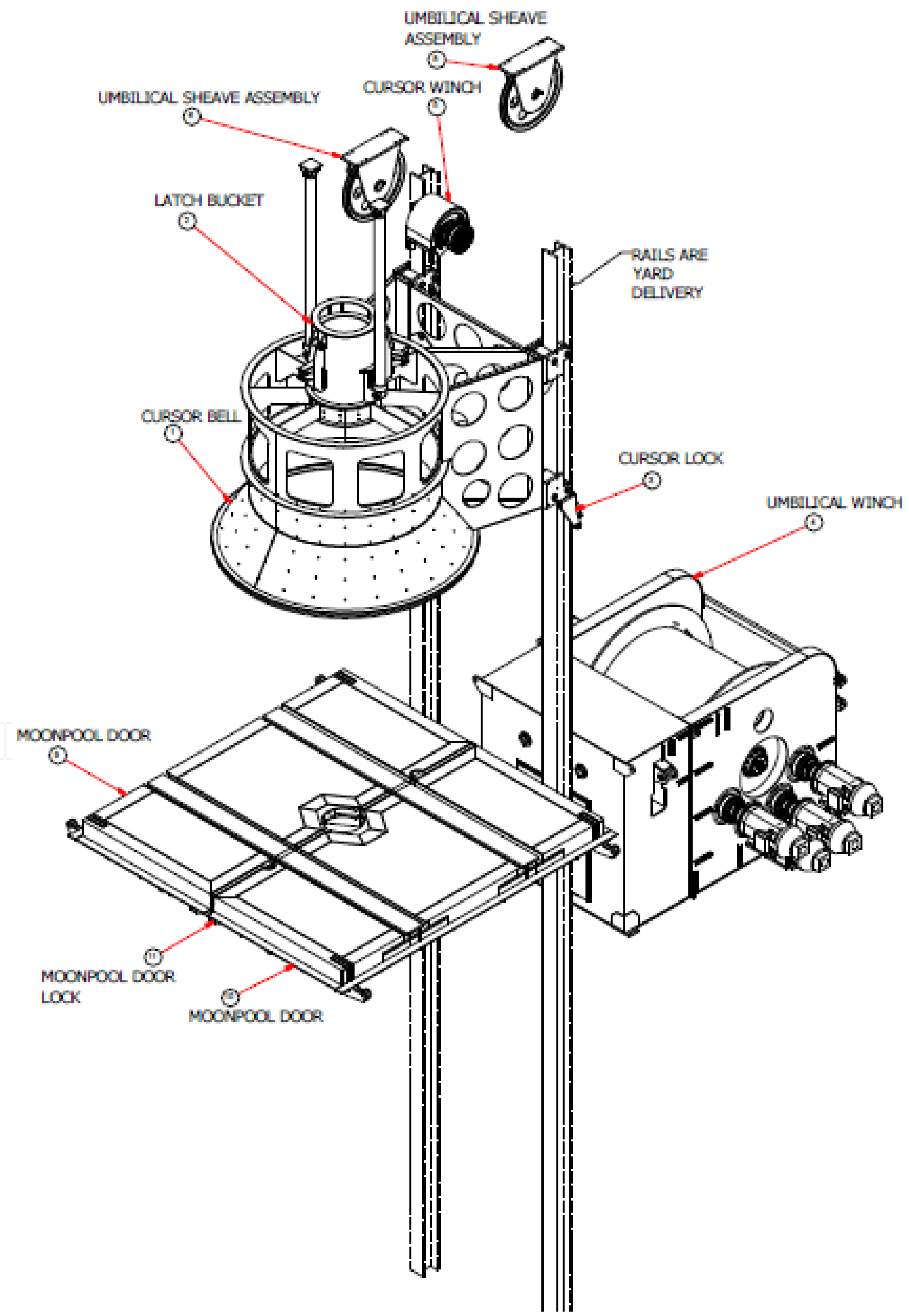


Figure 6: LARS Components of WROV moonpools with dimension 4,8 x 4,8 meters.

All components are specially designed to be integrated in the vessel structure. Ship designer and Hydramarine have in close co-operation designed all brackets, hinges, rails and superstructure in the ROV hangars according to the component outline dimensions, functionality and reaction forces. No components are easily removable).

2.4.1. *Umbilical winch (15T)*

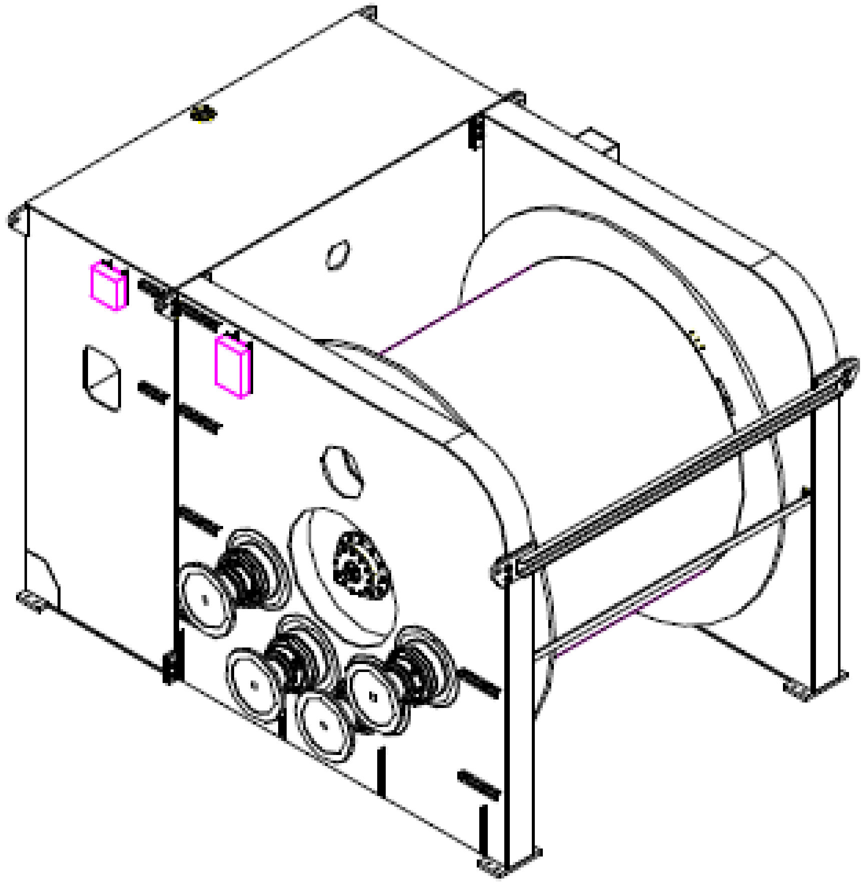


Figure 7: Umbilical winch.

The WROV umbilical winch works in conjunction with the ROV cursor system. It consist of a Lebus grooved drum suitable, enabling an effective travel of 2500m. The drum is supported in both ends, and powered by 4 electric motor/gear units connected to the drum through 1 off tooth rings. The motor/gear units are equipped with electric fail safe brakes, which require a positive electric power to release, lack of electric power will apply brakes and motion will cease. The spooling device is of hydraulic operated type by use of a temposonic cylinde.

The winch is operated from the ROV control chair or the handheld control console in the hangar and interconnects with the ROV cursor system. The cursor winch “slave” in CT mode to the WROV winch during launch and retrieval through moonpool.

2.4.2. WROV umbilical block

Figure 8: Umbilical block.

The umbilical blocks are mounted in top of the ROV hangar. It is designed to guide the umbilical from wire trunk to centre of moon pool.

2.4.3. Cursor system design

The WROV cursor system consists of MacG HydroMarine equipment integrated in yard delivered structure. The vertical guiding rails are manufactured and installed by the yard during building of hull. It is of importance that both rails are parallel and are within the same horizontal distance throughout the entire moonpool and hangar. The cursor itself has a tight guiding tolerance on one of the rails while the other has more tolerance slack for adjustment.

Figure 9: Vertical guiding of cursor system design.

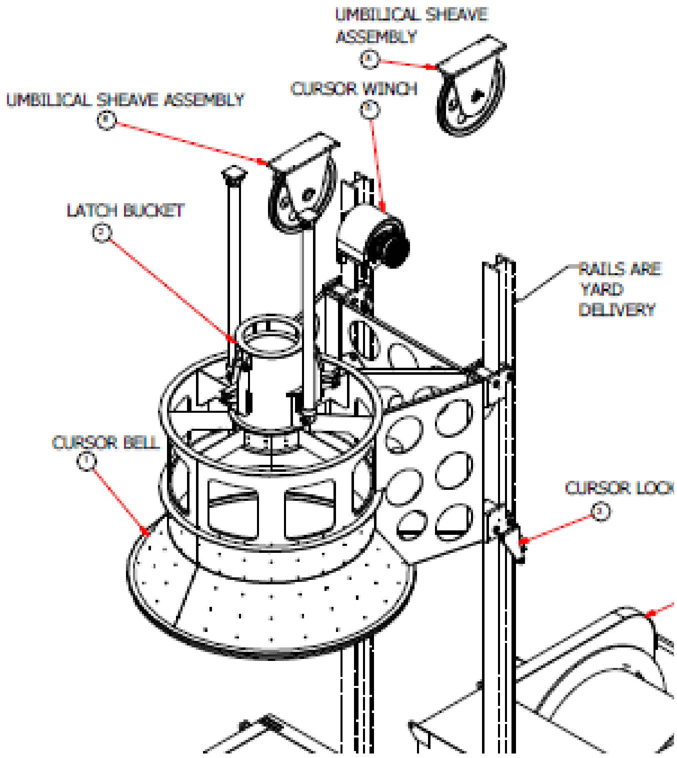


Figure 6: LARS Components of WROV moonpools with dimension 4,8 x 4,8 meters.

According to the cursor, bell slides up and down on the rails supported by rollers as are shown on Fig.6 of above.

The cursor bell is hoisted or lowered by a cursor winch. During launch and recovery of the ROV, the winch is to handle only the weight of the cursor. Winch is to be set in constant tension (CT) mode, and the CT value is to be set close to the cursor weight.

When lowering the cursor bell a revolution encoder will monitor the cursor position all times. For safety reasons a mechanical end stop is welded on each of the rails in bottom position of the moonpool.

The moonpool also includes a door system for opening the moonpool during launch and retrieval. The door consists of 2 hinged parts hydraulically operated from the hangar, handheld by the operator console. The doors are equipped with hydraulic locks giving feedback to operator of open/close position from proximity sensors.

To prevent excessive ingress of water into the hanger during transit or operation, the doors are sealed to the moonpool edge using a rubber gasket as shown on drawing of below:

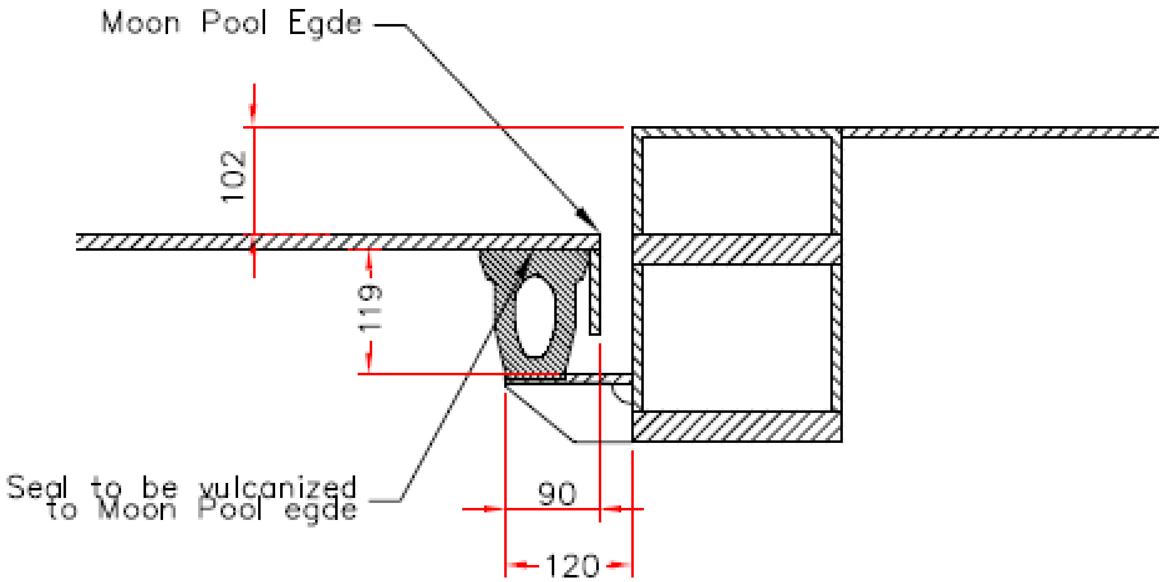


Figure 10: Moonpool edge.

2.4.4. Cursor winch

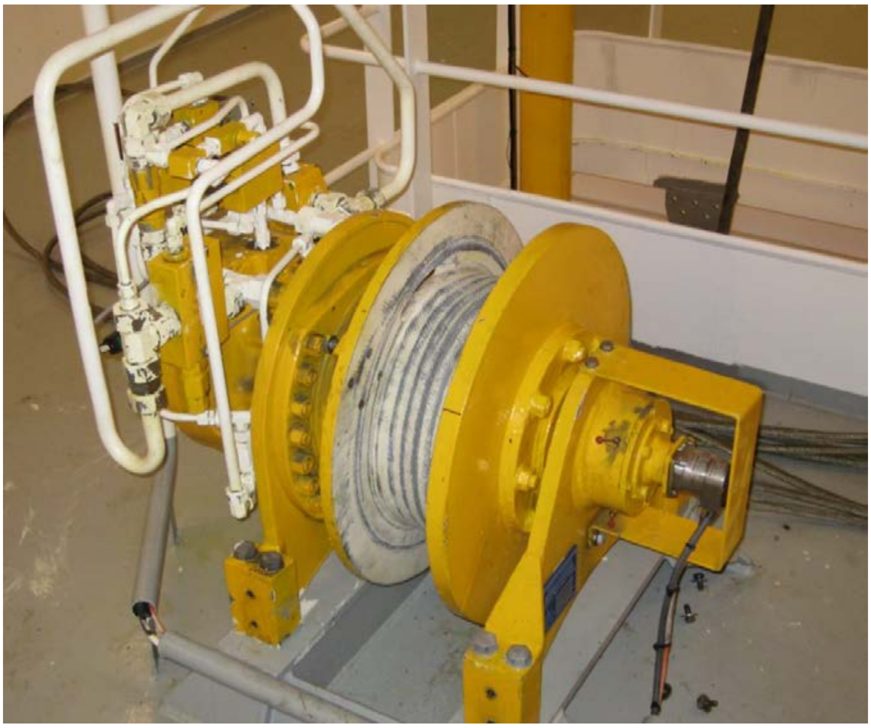


Figure 11: Cursor winch.

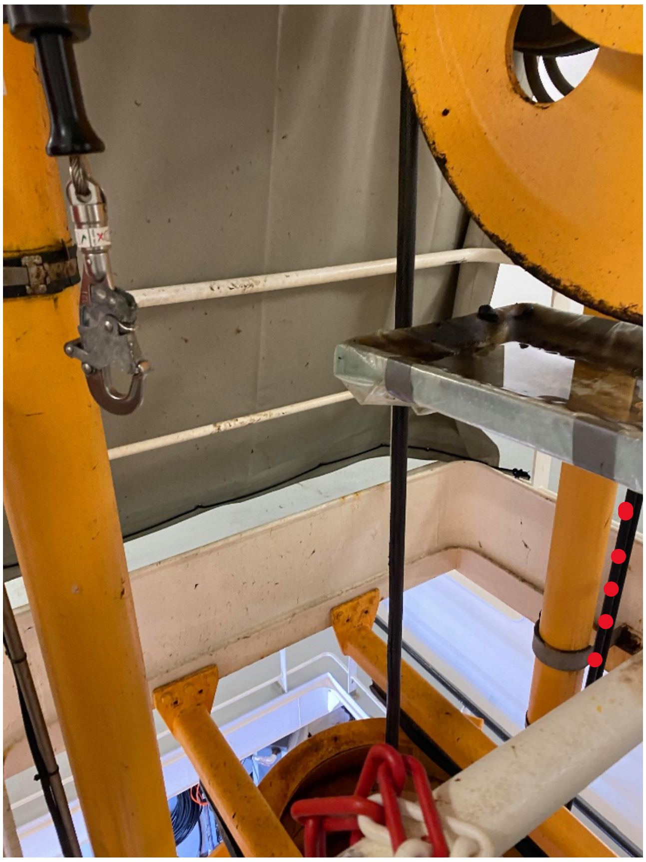
The cursor winch operates as an important part of the launch and recovery system. It consists of a drum connected to the winch foundation trough a radial piston hydraulic motor with a failsafe brake between drum and motor. The operation of this winch is done from the handheld control console in the ROV hangar.

The winch is indirectly to ensure the cursor follows the position of the umbilical winch as it is sensing the load of the cursor bell in CT mode.

The winch does not act as a slave and run on position signals from the umbilical winch.

The winch operates in 2 modes, normal and constant tension. Normal mode is used for lifting or lowering the cursor in the hangar when the TMS is either submerged or secured to deck. Constant tension mode is used during launch and recovery of the TMS/ROV.

2.4.5. Cursor



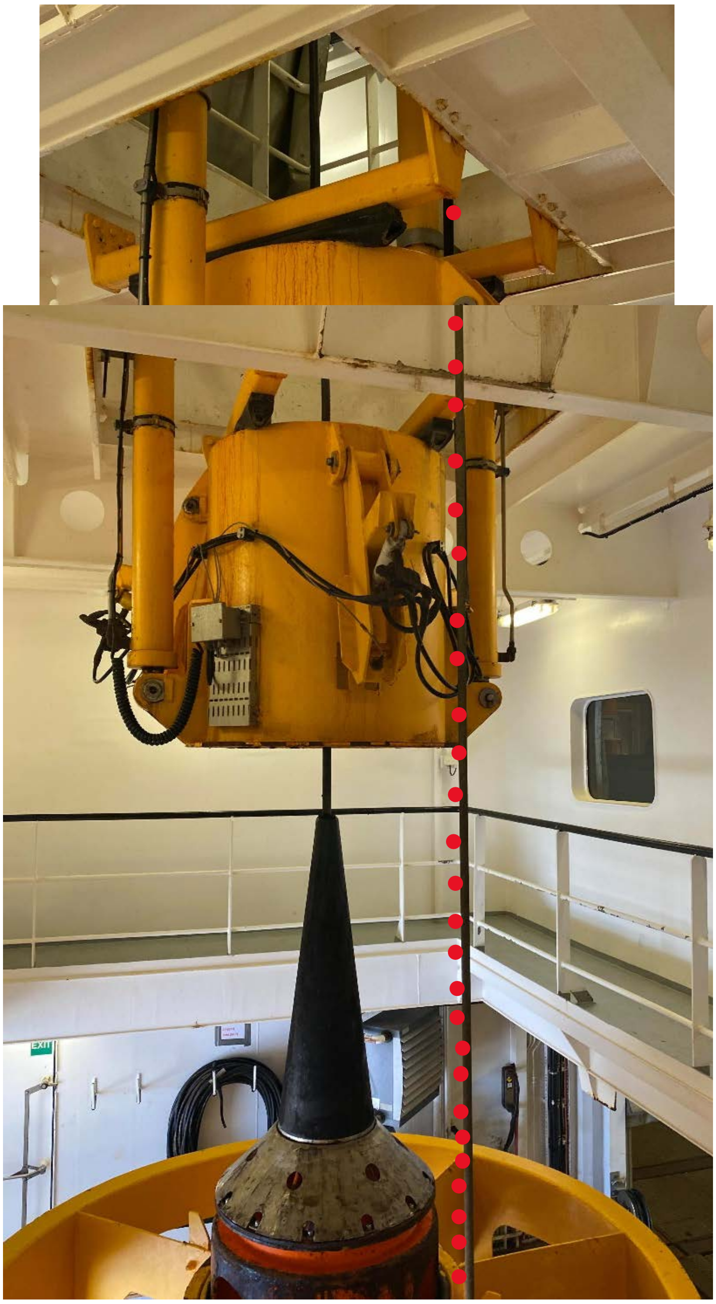


Figure 12: Cursor itself.

The ROV cursor bell is design for safe guidance of TMS/ROV through the ROV moonpool. The cursor is a circular bell-shaped frame supported to the guiding rails by welded on plates. Cut outs are made in the structure to decrease the weight of the cursor. To ensure a smooth entry of the TMS into the cursor, rubber plates are mounted/glued on the inside of the bell. Inner diameter is designed to suit the outer diameter of the TMS. This to minimize any horizontal movement of the TMS during

launch and recovery. The cursor has bolted rollers (with internal bronze bearings) positioned in both X and Y-direction towards the rails to ensure the cursor is held in a stable position during vertical travel.

The cursor can be parked in various positions. A set of hydraulic locks are mounted on the rails to unload the cursor winch when the system is not in service. See picture below.

The cursor interacts with the latch bucket in the system. For securing the TMS during transit or non-service mode, the TMS and cursor can be hoisted to the top of the hangar until the TMS enters in the latch bucket. When latches are engaged, the cursor is fixed to the TMS and the cursor cannot be operated in normal mode.

There are mechanical end stops welded onto the guiding rails in the bottom of the moonpool to prevent the cursor from dropping out of its guiding rails.

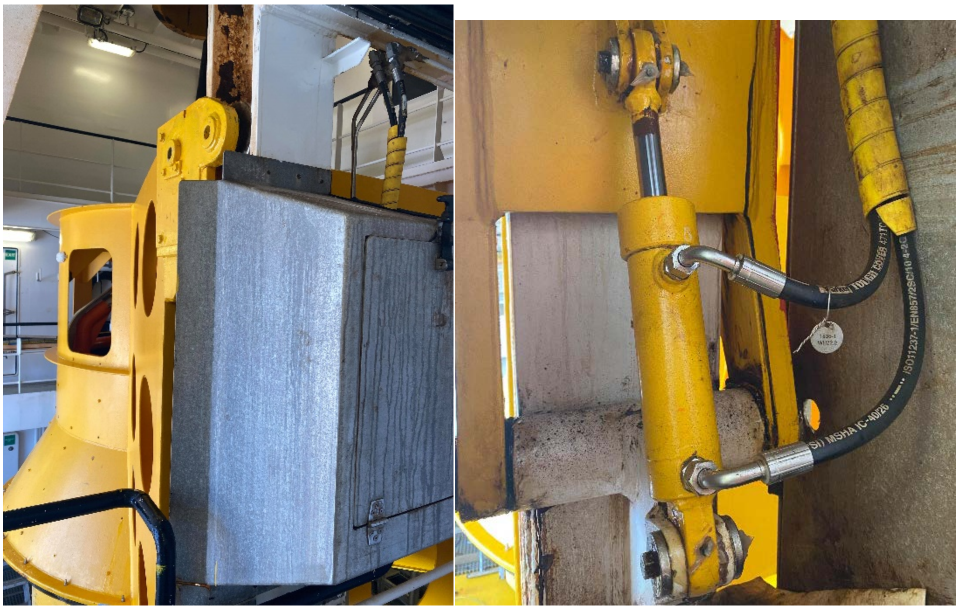


Figure 13: Hydraulic system for cursor locks.

2.4.6. WROV HPU

The WROV winch is connected to a dedicated HPU. The HPU provides oil cooling to the el. motors of the WROV winch. In addition to the HPU, a break resistor is installed to handle the excessive power of the electric motors. The resistor is fresh water cooled.

HPU data:	
Number of pumps (n)	1
Voltage	400V
Power consumption	3.5kW
Working pressure	10 bar
Flow	27ltrs/min

Figure 14: WROV HPU.

2.4.7. ROV Moonpool hatch

Figure 15: Picture of ROV Moonpool hatch.

The Moon Pool Hatch arrangement consists of 2 identical doors(incl. skid rails) and the locking system.

The moonpool hatch system is fully hydraulically operated from the handheld control console located in the ROV hangar on main deck.

The moonpool doors are operated from the handheld control console located in the ROV hangar on main deck. To open the locks, the doors have to be lifted slightly upwards to unload the weight from the door on the locks.

The hatches are equipped with hydraulic locking mechanism to ensure the hatches are secured when in transit. The locks are fitted with proximity sensors giving feedback to the control system and operator of the lock position.

The edge of the moonpool is fitted with a rubber seal, preventing seawater entering the hangar area. A same type of seal is also attached to one of the doors for internally sealing of the centre line of the doors.

There are no sealing in the area around the vertical guide rails. However, a hinged plate is fitted to each rail to prevent sea water spray into the hangar.

The hatch includes skid rails corresponding with the aft deck skid rail system. ROV’s, TMS’ and other equipment up to 30T can be skidded onto the hatch.

As shown on the drawing of bellow *Figure (16),* holes for umbilical and cursor wire entry are made in the doors. This enables the doors to be closed while the TMS/ROV is deployed.

The holes can be plugged using plastic caps and secured by a simple locking mechanism.

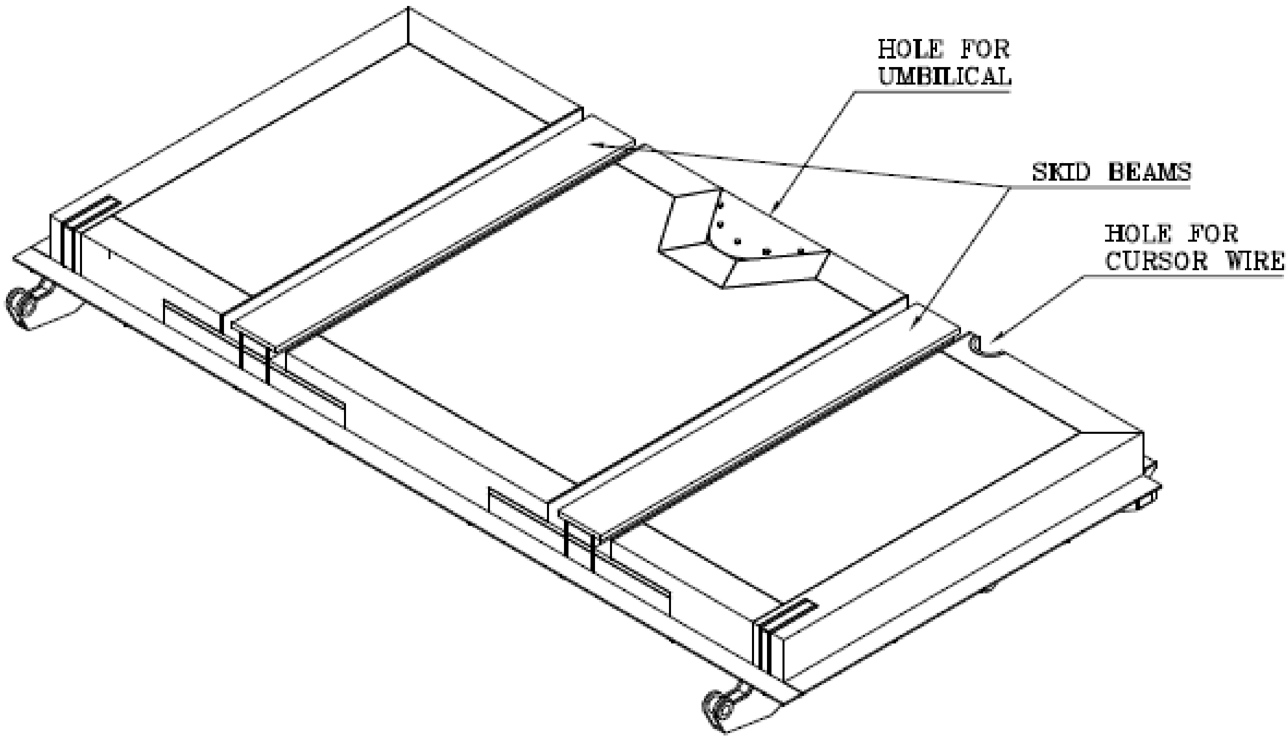


Figure 16: Drawing of ROV Moonpool hatch.

All doors are equipped with hydraulic locks as shown on the drawing of below *Figure (17).*

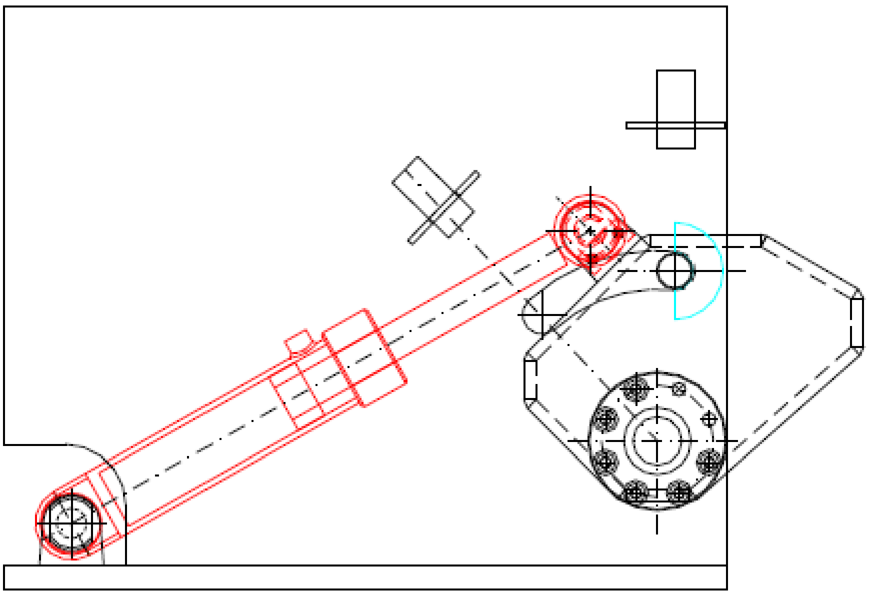


Figure 17: Drawing of hydraulic locks.

A proximity switch is giving feedback to the control system and operator of the position of the hatch lock. The lock is designed to maintained locked position if hydraulic supply is switched off. Also the cylinder operating the lock is not powerful enough to open the moonpool door if door is closed.

2.4.8. Latch bucket

Figure 18: The latch bucket.

The latch bucket is located at the very top and centre of the ROV hangar. The main purpose of the bucket is to secure the TMS during transit or maintenance. 2 vertical mounted cylinders are attached to the bucket and fixed to the top structure.

There are 3 hydraulic operated latch dogs on the bucket. The latch dogs when closed interlock in a dedicated groove at the top of the TMS, transferring the load from the umbilical winch onto the vertical latch cylinders. This again allows for personnel to do maintenance or repair work under the TMS/ROV. During a latch sequence, the TMS must be lifted until it touches the bucket. The latch dogs are fitted with proximity sensors giving feedback to operator of dog position, lock/unlock. The latch bucket is fully remote operable from the handheld control console located in the ROV hangar.

2.4.9. Manoeuvring station equipment (for operating chair)

All winch functions can be operated from the control chair. But, due to safety reasons, the operation of moonpool doors, cursor and latch bucket are to be operated from the local control station in the hangar.

The following equipment is delivered for the ROV control chair:

- Emergency stop button
- System on/off button
- Touch screens left/right
- Joystick
- HMI screen
- Video monitors

2.4.10. ROV hangar handheld remote control

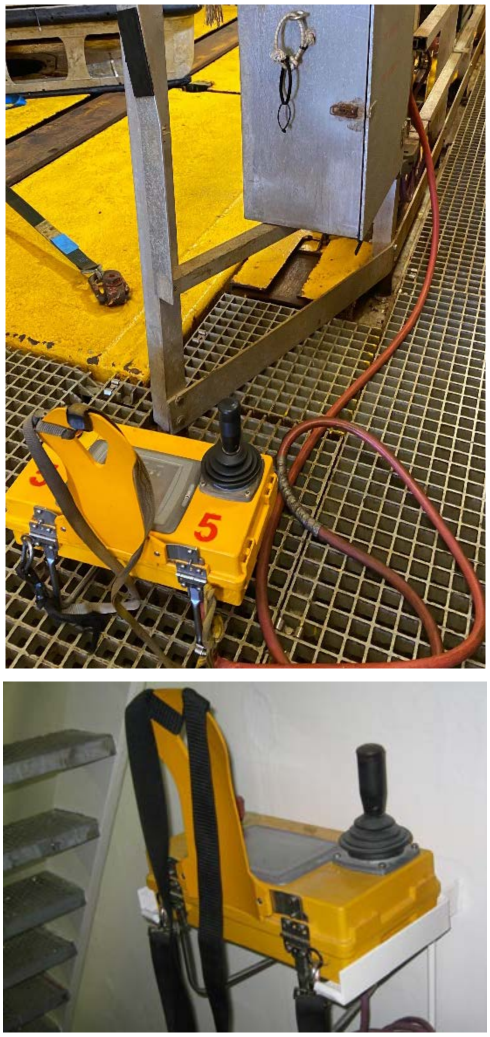


Figure 19: ROV hangar.

The local remote stand is located in ROV hangar on main deck, one station for each WROV system.

From this panel the following equipment is operable:

- WROV HPU
- Moonpool hatches and locks
- Cursor winch and cursor locks
- Latch bucket
- WROV umbilical winch

There are 8 off cameras installed in various places surveying the WROV system and MHS (Module Handling System). All cameras give input directly to the ROV, and to the MHS, control system giving the operator the choice of what cameras to view.

The cameras are located on the following areas:

- PTZ (Pan-Tilt-Zoom Camera) Camera in MHS Hangar
- Winch camera on Main Winch.
- Winch camera on Guidewire 2.
- Winch camera on Guidewire 3.
- Winch camera on Guidewire 4.
- Winch camera on Work ROV winch starboard side.
- Winch camera on Work ROV winch port side.
- Winch camera on Observation ROV winch.

2.5. Launch and Recovery OPERATION in moonpool

The LARS operates in two different modes: transit for wave height (Hs) <=11 meters and operation for Hs<=5 meters with speed=0 knot.

Transit mode

1. Ship transfer to and from operation locations.
2. Weather condition giving Max Hs<=11 m.
3. Speed>=0 knot.
4. Wind speed <= 50 m/s 10 min mean value at 50 m above latitude (LAT).

During transit the work ROV (WROV)'s are fixed to pallets or moonpool doors and sea fastened. Pallets are locked to skid rails during transit.

Operational mode

5. LARS handling of any kind.
6. Significant wave height Hs<=5 m.
7. Speed of ship = 0 knot
8. Wind speed <= 30 m/s 10 min mean value at 50 m above LAT.

For vertical movements WROV assemblies are being guided with the cursor system.

Vertical handling of WROV assemblies:

The ROV moonpools of size 4.8x4.8 m is located in an indoor environment at main deck and are supplied with hatches, a guiding cursor and a heave compensated umbilical winch system for vertical movements. The system can handle ROV/Tethered Management System (TMS)/Toolskid up till 15 T SWL to a max depth of 2500 m at sea state Hs<=5.0 m.

The 4 general phases of the LARS of WROV are following: System on; System off; *Launch*; Recovery; Latch Assembly.

System On

1. System On/Off switch, in ROV console, is set to On (Key switch).
2. System On is selected on the operator terminal.
    - Main contactor is entered and start request is sent to **PMS.**
    - Start accept feedback from **PMS.**
    - Start acceptance can be overridden by activating the override button after the request is activated.
3. Local control or ROV control is selected by pressing *''Accept Command''* on the current screen.
4. HPU starts. Both pumps.
5. Operation mode is selected from screen.

System Off

1. Operation mode is disabled from screen.
2. Both pumps on the HPU are stopped.

    - Pumps cannot be stopped in the normal way as long as a mode is active.
3. System off is selected on the operator terminal.

    - Main contactor lays out and operates.

    - System Off cannot be selected as long as a mode is active.
4. System On/Off switch, in ROV console, can be deactivated to block operation of ROV system from deck.

    - Deactivation of the switch during operation causes the system to stop immediately. Mode is deactivated, pumps stop and main contactor shuts down.

<u>Launching of WROV</u>

Launching of TMS / ROV can only be performed locally from the deck.

Driving of ROV winch can only be done when TMS / ROV is deeper than the recovery point.

1. **TMS / ROV is parked on hatch**, Cursor parked on locks. All operation takes place from the deck.
2. **Cursor winch mode is activated.**
   - The cursor is lifted up to the latch assembly so that it is free from the locks.
   - Cursor locks open.
   - The cursor is lowered towards the TMS, stop 10-20cm before the cursor settles down on the TMS.
   - To disable the cursor winch mode.

   NB! The cursor must not be placed on the TMS when the TMS / ROV is on the hatch.

3. **WROV winch mode is activated.**
   - TMS / ROV is raised to the cursor. It is important that the TMS is run all the way up to the cursor.
   - Cursor CT is activated.

   NB! Cursor CT must not be activated when the cursor is hanging freely. It will then fall freely.

   The system checks distance to TMS so that it is not possible to activate CT when distance to TMS is too large - *To avoid damage to equipment, it is important for the operator to check that the cursor is down before CT is activated.*

4. **Select Hatch Operation and activate Hatch Control.**
   - Open both hatches and confirm that the hatches are open before disabling Hatch control.

     Hatches can be operated while WROV mode is activated and Cursor is in CT mode.

     The ROV must be lifted clear of the hatches before these can be driven.

5. **Lower the TMS/ROV down through the moonpool.**
   - The cursor will follow until it stops at the bottom of the moonpool.
   - Continue to run TMS / ROV until it is deeper than Recovery depth
6. **Disable WROV winch mode and disable the 'Release Command'.**
7. **WROV winch can now be operated from ROV Control.**

Recovery of WROV

1. ROV is at the sea.
2. Umbilical winch is driven up to the recovery point. From ROV control or from the local control.
3. Winch automatically reduces speed and stops when it arrives recovery point.
4. To go up more, it must be confirmed that the system is ready for recovery.

   When is the system ready? When the 3 following is done:

- Cursor in lower position.
- Cursor winch in CT mode.
- Hatches opened.

5. TMS / ROV is driven to go up at a somewhat limited speed.

   When TMS comes to the cursor, WROV winch take some of the load from the cursor and it will follow up.

6. When the ROV is at the deck height, the speed is even more limited.

   From this moment, it is not possible to drive from ROV control. The rest of the operation must take place from deck.

7. TMS / ROV are raised so that they are above of the height hatch.
8. Shutters are closed now.
9. TMS / ROV is placed/parked on the hatch, and the cursor is lifted up and is hung by the locks.

   The cursor should not be in CT when the ROV is lowered/placed on the hatch, but it should by stopped a little before (10-20cm before).

   The cursor is raised to the upper position. Locks are closed and the cursor is parked on such locks.

Latch assembly

Latch assembly cylinders can only be lowered when the cursor and TME are locked in the latch assembly

1. TMS / ROV and cursor clock are raised in WROV mode until they receive latch assembly and load increases in proportion to the weight of TMS / ROV
2. Latch assembly locks are locked.

   The load in umbilical must be over during 5h for latches before it can be operated. This is to prevent that locks can be opened accidentally.

When latches are in (Indication from each lock) the load in the umbilical is lowered to approx. 1h.

3. WROV mode is disabled and Latch mode is enabled.
4. Cursor and WROV winch are set in CT.

   Load in umbilical must be less than 1.5h to get CT activated.

5. When Cursor and WROV are in CT, the latch assembly can be moved up and down with a joystick.
6. If the latch assembly is to be run without WROV or Cursor in CT must override activated.
7. Latch assembly locks are reopened by activating WROV mode, pulling up tension in umbilical and then open the locks.

3. Methodology

In this chapter will be given a more specifically description of the two different information gathering methods that was before named in the chapter (1.1.), and that have been used to answer the RQ of this thesis.

This study has been a variety of literature studies, and conversations in their different variants like by mails, telephone and ''in situ'', and also with considerations of how the industry today is currently working in this specific system. These mentioned gathering methods lead to this thesis being investigated under a qualitative approach.

3.1. Literature study

There have been two processes for carrying out the literature studies in this thesis:

1. Searching online about actual operation of the LARS regarding ROVs with moonpools, and tools used to carry out this operation. This was done using google and search words similar to,

and in different combinations of: subsea, ROVs launching, LARS, automatized operation of LARS, winch capacity in LARS, Hs of different launchings, different type of LARS, and so on.

The object here has been to find tools, methods and components of such systems, collecting factual specifications.

2. Searching online for reports, articles and written scientific reports on the subject. I used different scientific's webs to read those reports that I considered of relevance to this researching. I also used the databases of Petroleum Safety Authority Norway (PTiL) [7] and International Marine Contractors Association (IMCA) [8] to collect valid information in investigation reports of this operation. And by finally, it was taken contact with some members of the Norwegian Maritime Authority [11] with the Department of Risk and Analysis, where were collected also much other accident reports concerning to LARS and ROVs.

3.2. On board

The Deep Ocean's opinions have been largely considered when designing this thesis. The visit to the vessel EDDA FAUNA(from D.O.) have been an invaluable experience. It is a leading subsea service company which has been involved in a lot of offshore projects. They have been always involved in both, the engineering, planning and construction of many of projects. So that's means, they have a great experience of all stages of the LARS's operation.

3.2.1. Visiting the vessel EDDA FAUNA

A qualitative approach is good for getting people´s the understanding of given situations [9]. Connected to this affirmation, a qualitative researching could be enough good for getting people´s understanding and interpretations of for example, the launching of the ROV. The qualitative approach has advantages you are also able to get a proximity, a close relation to the persons you talk with.

I visited the vessel and met with the operators there. Through the operator's explanation ''in situ'' of the operation, and in conjunction with the helpful guiding of the extern supervisor, I could understand the challenge and the approach this company carry regarding the LARS. After to finish with explanation from the operator, and some questions from my site for a better understanding, It was took the conclusion of there is a challenge in the launching of the WROV in its moonpool, exactly in the splash zone.

3.2.2. Discussions with the engineer J.R.

The company DeepOcean is a leading subsea service company and has been involved in a lot of offshore Projects, and they have been always involved in both, the engineering, planning and construction. So that's means, they have great experience of all stages of the LARS.

Interview questions/feedbacks through conversations, mails, telephone with the engineer Jostein Røed have been attached in <u>*Apendix A.*</u>

4. Results and discussions

This chapter will describe firstly why have been chosen the LARS trough moonpools. Then it explains which possible elements were found out in this study and could be used to get a desired automated LARS's operation. During the describing of these new approaches of the LARS, at the same time, these findings focused to the automation will be discussed.

4.1. Why trough moonpools?

For autonomous vessels, according to this investigation it has been expected that moonpool systems in LARS are the easiest to make automated, being that, with over the side systems, it is needed to watch the waves, to take in account the size of waves and use some 'aim' when recovering in high waves.

However, in moonpool systems the vehicle is locked into a cursor frame while going through the splash zone. This eliminates a lot of risk. So, this is the main causes why I have taken LARS of the vessel EDDA FAUNA as bases in this investigation.

In addition, it is needed to consider every vessel in a specific way, being that, every one has it owns design on deck, with different characteristics too in the LARS.

For example, in the case of EDDA FAUNA's LARS, it is the forces created by the surge in the moonpool that will tell maximum Hs the system can handle. But this LARS was designed with an air pipe system down moonpools which help to get a maximum high wave according requirements. By example, if the LARS can handle Hs 5m it should be safe to launch and recover the system in Hs 5m, on top of that there are safety margins.


NOT FOR LIFTING WITH LOAD

Figure 20: Air Pipe System of EDDA FAUNA.

4.2. The splash zone

The launch and recovery operation in moonpool have been described above in the Cha. (2.5.). But taking special focus in the launching, when lowering down the TMS/ROV down through the moonpool, appear in scene the splash zone. It is zone is the moment where the WROV take contact with the surface water. Please, see Fig. (21).

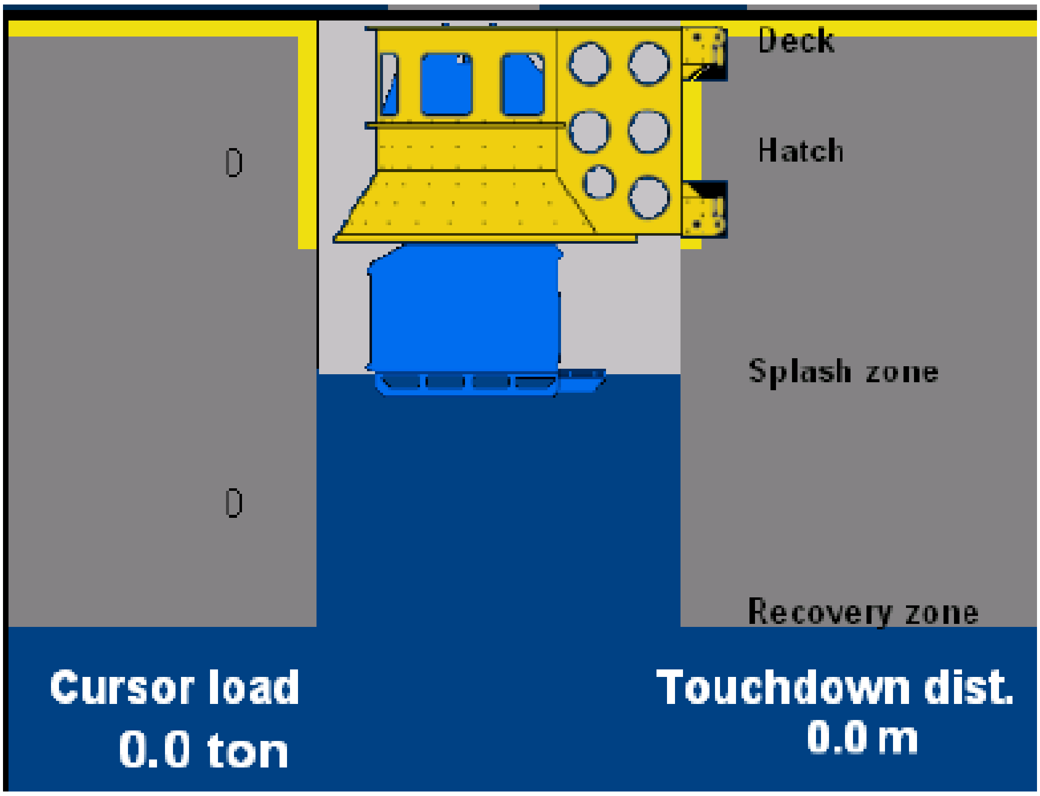


Figure 21: Splash Zone's drawing.

The launch and recovery operation in moonpool has been described above in the Cha. (2.5.). But taking special focus in the launching, when lowering down the TMS/ROV down through the moonpool, appear in scene the splash zone. It is zone is the moment where the WROV take contact with the surface water. Please, see Fig. (21).

In this phase, the operation is under responsibility of the precision of the operator who launches into the sea with the remote control of the ROV hangar. The visual supervision of the operator in the launch operation, joined to bad weather conditions, slows down even more the launching, in addition, it damages the WROV due to a big impact which usually is done in the splash zone.

So here the object is to find the way that this operation does not slow down as much as it is today. This object is joined to the idea to minimize as much as possible the great impact of the ROV with the surface of the sea in the first contact with waves, that let to damage the ROV.

Regarding the LARS in moonpool of EDDA FAUNA., the operation is done nowadays with the presence of the operator (locally). So, it has been considered that it can be necessary to integrate the used of new technologies to assure 100% that the splash moment will be the least harmful possible, not leaving that above responsibility of the weather conditions, or of the operator's experience and skills.

4.2.1. Parameters

Next step it has been found out the average velocity and acceleration that operators use in winches nowadays on the locally LARS's operations (see Fig X). These standard measures can be used as the initial velocities and accelerations in winches, to set up and program the automated deployment of the LARS, getting in this way two advantages: faster as needed and lessens the possibility of damage of the ROV.

	Hidraulic winch	Electric winch
Velocity (m/s)	*1,34*	*2,44*
Acceleration (m/s2)	*2,43*	*3,93*

Figure 22: Parameters.

4.3. Automated LARS

The exploring ways of designing configuration to get an automated LARS are in forward motion and evolving by those companies which work in designing and constructions of this system. But, for example regarding our example-vessel EDDA FAUNA, which has already designed and constructed LARS, to modify it to be fully automated it is not so easy. Thinking in replace the hydraulically system by an electric system, does not seem be viable. It can be said to be a cost-based issue.

It has been found that some LARS created ''inhouse''. It consists in the conjunction of these different elements, like the gyro of the vessel, PLC (Programmable Logic Controller), Sensors input. A PLC is the "brain" that activates all components to carry out activities that are potentially dangerous for people, very slow or imperfect.

With this alternative configuration, it has been possible to automate the operation in some way, but the ROV operator should still follow the task on deck (locally).

To get a totally automation of LARS in moonpools like in EDDA FAUNA, it can be also controlled by the gyro, as said some lines above; Then, gyro can give input to the LARS (trough *PLC ''the brain''*- in case that is required to use the PLC). And finally, it must be also installed a sensor input which will work in conjunction with the gyro. The Gyro will calculate the speed of deployment through the splash zone. But, these issue will be discussed in the three following chapters, *Winches, CCTV Cameras and sensor input.*

4.3.1. Winches

Winches can be powered in two different ways, hydraulic or electric power. Choosing the right winch will be based on review of several factors, like e.g.: what will power the winch?, how will the winch be used?, how tough is the job?, how long will the winch need to perform work?, and so on.

Regarding the case of EDDA FAUNA, which was built 12 years ago, he LARS system was designed with hydraulic winch that is powered by hydraulic system. In this system a hydraulic pump is needed to operate the winch.

In general words, a hydraulic winch is built to withstand a big job, with the power to handle it effectively, but however, If we take the case that it would be needed to start a LARS design/vessel design from the beginning, then it could be chosen electrical which instead of hydraulic winch due to, thinking in the programming to became automated, it is much easier to control the speed and acceleration in electrical winches.

An electric winch typically uses the battery of a vehicle in order to power the winch's motor. Electric winches are the right choice for quick, occasional, and light use, as in ATV recovery, as they do not require as much in the way of power. But, this option has also an inconvenience, it is possible for an electric winch to drain a battery quickly.

Important also to name that it takes a huge importance the weight of the ROV/TMS/CURSOR/LatchBeem which transfers the system through the splash zone safely. So, weight is essential to avoid slack wires and thereby unknown snap loads in the wires/umbilical.

It is convenient to say that we have found that velocity in an automated operation could be approximately the same than in a manual operation. Anyway, it follows being, it is an important difference between the manual or automated operation, being that, with CCTV cameras and sensor input installed would get a gentler way to the deployment of the ROV. Here it will appear a kind of challenge also; it is the training of the crew that would be totally required before automation will start it operation on board.

4.3.2. Cameras CCTV

After some discussions with personal qualified, and following Standard DNVGL-OS-D202 Automation, safety and telecommunication systems [10] it has been confirmed that the cameras which fit adequately to the operation of LARS are cameras CCTV (Closed Circuit Television).

This expression "Closed Circuit" means that it is an installation of directly connected components that create a circuit of images that cannot be seen by another person outside of it, that is, they cannot be seen by anyone with an antenna or another team to receive them.

To install them requires relatively low costs with regards to installation, maintenance(where is normally included maintenance support during the 24 hours of every) and durability. This system is used normally for dangerous and corrosive environment, like in the LARS operation and others in subsea.

Manufactures must include the initial design, engineering, installation, tests and detailed documentation regarding specifications of every LARS.

The new generation of modular CCTV architecture offers access to multi-CCTV systems. The operator connects to the local CCTV system, but has access and control over any external CCTV system for which he is authorized, giving to operator control over a practically unlimited number of cameras deployed over areas where the operator is. Otherwise, in the conventional LARS, even If operator would have not access just looking from deck.

The initiative needed to be taken here, and was not possible to carry out in this investigation, is to visit the LARS again; and with the help from crewmembers who were involved in the operation and/or in the design and construction of the LARS, to decide how many CCTV cameras are need and where could be placed.

With just an operator who will control all critical areas from a central control point (control panel), it can respond to a series of simultaneous events more efficiently than multiple individuals located on deck at the time of the operation, improving on this way the efficiency, safety and ensuring better productivity; In addition, the distribution can be monitored wherever on the vessel.

Figure 23: Configuration of CCTV cameras.

It can be accepted just those CCTV cameras which offer complete systems and consist exclusively in units with Type Approval. *Type Aproval* [12] is a procedure used to confirm If such product system goes regarding to predefined certifications. These requirements are based too in the normative DNV for High Velocity & Light Craft and Det norske Veritas Offshore Standards.

The DNVGL standard for Certification 2.4 establishes the environmental test specification that applies to all automation, safety and telecommunication systems. The standard covers Electro Magnetic Compatibility (EMC) and environmental physical tests such as vibration, temperature and humidity. [10]

Regarding the certifications in the European standard according to the ATEX directive 94 / 97EC, IECEx., there is a complete range of camera and monitor stations for hazardous areas such as LARS.

4.3.3. Sensor setup

There is an extensive range of sensors that exists in the market today. But, according to this investigation, it has been taken special focus in motion sensors. Specially, incremental encoders decoders that meet the stringent requirements of precise positioning and velocity sensing, so it have been thought that this kind of sensor could carry out the required function in the LARS of moonpools.

The difference between encodes and decodes it that encode is used to create and decode is used to interpret and understand. So, initially, the system can be controlled by PLC and extensive use of <u>decoders</u> to be programmed to automate the LARS.

<u>The place</u> where sensor should be installed is in the winches and cursor to control the velocity to be carried out. In this thesis, it has been caught the parameters like velocities and accelerations that are used nowadays in the conventional LARS. It can be a good reference, as standard data, when automation will be desire taken in practice.

But it cannot be used a permanent guide to automate the LARS, being that, every LARS has it own requirements. So, where it will be placed sensors it will depend on every LARS.

Finally to comment, that there is an issue that became a challenge is to think in installing sensors that will measure the heave and have the winches to compensate for that: to place in the button of the ROV a sensor which give signal/feedback and indicate to the winch and cursor a more exact movement of the waves of sea. I mean, a sensor bellow in the button, to orientate on which movement have the waves, and at the same time, to help to change with quick reaction to the winch and cursor. In this case, I think it could be required the use of both, encoder and decoder. But this idea could not have been verified by experts of the area. It can be a possible study way in the future.

5. Conclusion

The goal for this project was to get a better understanding of LARS in moonpools to go through the system and operation, for taking conclusions faced to the desired automated systems.

It have been taken as ''guide'' vessel, Edda Fauna, to go on board and get a general overview on how it is working the LARS operation nowadays.

Then it has been seen in detail every subsystem and component of the LARS, with the goal to obtain a better understanding to possible solutions in the automation of the operation.

After that, we have clarified why has been chosen the LARS in moonpools and not over the side, by now. But that one, over the side, could be a strong theme of investigations in near future too.

The real goal of this thesis have been how to convert the operation from manual to remoted, being that, o carry out remotely can contributed in much positive aspects like do it in less time, economical and safety aspects to crewmembers and equipment.

It would be desired to put in practice all these knowledge, but the situation of nowadays with the COVID-pandemic (and other reason) did not let us continue developing this project on board. Anyway, with the great help of some experts in LARS operations and its construction and design, it has been possible to gather valid information about how could be got the automated LARS.

There are much investigation areas according the automation of LARS. But the closest further work can be to work in obtaining the arrangement of the CCTV cameras and sensor input, deducing on board strategic areas to be placed this components. Unfortunately, this cannot be possible until we have finished winning to the COVID- pandemic.

6. Further work

- I have visited one time the vessel. On board I got a good overview and explanation on how LARS in moonpools is working today. But, due to restrictions concerning to COVID-19 pandemic *(between other reasons)* was not possible to develop this the project ''in situ'', as was thought in the beginning. Therefore, I have dedicated my thesis in exploring and studying the possible way to automate the LARS, dismissing the idea to comeback to the vessel for taking measures and possible positionings of cameras and sensors. Due to these reason above mentioned, communication with experts to collect information were conducted remotely via teams, mails and phone calls and questionnaire. Based on that, I think that a good further job could be to put in practice the automated LARS based on these conclusions and all information gathered in the exploration of this thesis.

- After that, one of the topics that could be investigated too is how automate the other main type of LARS system (LARS over the side mentioned in Chapter 2), being based on studies and explorations done in this thesis.

- Studying the way to convert the LARS in an automated operation, it has been considered that this will change the situation of operators. So, it would be a good issue to deep in crewmembers, and investigate the operation of nowadays, to convert the automated operation successfully.

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Apendix A

1. What is the name of the vessel where you previously worked with LARS automated?

2. What was your position there?

3. What tasks were you responsible for in connection with LARS?

4. A technical summary of the type of tools used to the LARS became automated.

5. Do you think that it was working OK? Or did ROV-operator find some difficulties in the task during the use in the launching operation e.g.? If yes - please try to explain which kind of failures or inconveniences gave this automated system (more focused in the launching).

6. Where were placed decoders that you named? Do you think it could be possible to get some drawings which indicated where are placed?

7. Was this system (Programmable Logic Controller + Decoders) connected in some way to ''gyro'' of the vessel?

8. Was the ROV-operator manipulating from deck ''in situ'' as in EDDA FAUNA? Or with this inhouse automated LARS could the operator manipulate from the control room, or other place?

9. Do you know about other vessels of Deep Ocean that are working with this same automated LARS?

10. How much time are you working with the vessel EDDA FAUNA? And, your position is probably the same, ROV Superintendent, rigth?

11.After to have been speaking with others, I have been informed at in other vessels that has been installed the automated LARS, they can not use it due to dont get to launch of ROV in a gentle way, so they had to comeback to use again the manual operation, due to ROV got more aggressive launch and consequently more damages than with the manual operation.

Regarding the vessel that you are working nowadays, EDDA FAUNA, it seems needed the investigation more focused in the splash zone, due to the two WROVs get a big impact with the sea waves in the launching through its own moonpools. Could you confirm me that? Please, comment the specific causes on why it has been thought that LARS could work in a better way being automated. I know now something, but is good for me to have your specific point of view on that.

12. As I have ''known'', the functionality of the active heave compensation (AHC) is carried out by sensors as MRU which measures of motion, velocities or accelerations are registered. This info that the MRU collect is used by some of the elements that were implemented in the inhouse automated LARS of SKANDI AGERCY. (I just try to understand the functionality of all parts together, in conjunction).

13. In SKANDI AGERCY: How was the AHC collaborating before the automated LARS? And how was AHC collaborating after, with the automated LARS? Some changes in the functionality of the AHC?. (The same, just ask that to a better understanding).

14. Maybe it is not possible, but... Is there any probability to obtain the drawing/arrangement of the inhouse automated LARS; or the configuration of how is the feedback of signals between gyro, PLC, decoders, and ''I don't know, but maybe to AHC''? If you have it and could send me, I will have totally confidential with it.

15. You said: ''The inhouse automated LARS could potentially been remote operated but there are requirements for pre & post dive checks on the ROV system today.'' Do you know where to find these requirements for pre & post dive checks of ROVs? It is regarding to some international organization as e.g. IMO?

16. It could be possible in some way to think in installing in the button of the ROV some proximity sensor which give signal/feedback and indicate to the winch and cursor a more exact movement of the waves of sea? I mean some sensor there bellow, to orientate on which movement have waves, and at the same *time help to change with quick reaction to the winch and cursor. Because if I am in the right these CCTV cameras give only the possibility to see in live and to record.*

17. Do you remember which type of sensors were used in the umbilical and cursor winch of SKANDI AGERGY to automate it? MRU? Inclination sensors? other?

18. Using the CCTV cameras could the system become entirely automated, without presence of humans on deck. But where exactly do you think that could the operator review the operation of LARS? Just From the control room or also would be possible to review cameras from the bridge?