

# Thesis Title

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## PROJECT

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## **Preface**

Some preface.

Trondheim, 2012-12-16

(Your signature)

Ola Nordmann

## **Acknowledgment**

I would like to thank the following persons for their great help...

O.N.

(Your initials)

## Summary and Conclusions

...

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# Chapter 1

## Introduction

Introduction to the problem, some background about the Survey Explorer project..

### 1.1 Background

Where do we stand? What has been done before?

#### Problem Formulation

#### Literature Survey

#### What Remains to be Done?

...

### 1.2 Objectives

The main objectives of this project are

1. Investigate existing solutions for HIL testing of autonomous boat
2. Describe implementation of sensors and data processing on Odin and/or Jolner for situational awareness above the surface.

3. Discuss complexity and solutions related to simulation of raw sensor data from Radar, Lidar and camera versus simulation of pre-processed data.
4. Specify interface between simulator and autonomous navigation system.
5. Specify system for logging and visualization of simulation in real-time and for post simulation analysis.
6. Necessary prototyping in C++ and MATLAB to verify assumptions.
7. Investigate which other agents (ships, small boats etc.) that can be interesting to implement as a part of the simulation environment.
8. Discuss methods for using the model as a part of an automated test environment related to ROS, MROS, scripting, repetition and regression testing.

## **1.3 Limitations**

## **1.4 Approach**

## **1.5 Structure of the Report**

The rest of the report is organized as follows. Chapter 2 gives an introduction to ...



# **Chapter 2**

## **Existing Solutions**

### **2.1 CyberSea HIL Simulator**

# Chapter 3

## Implementation and Simulation of Sensors

### 3.1 Sensors Implemented on Odin

A brief description of the sensors on Odin used for situational awareness above the surface. How is the data processed?

#### 3.1.1 Radar

...

#### 3.1.2 Lidar

...

### 3.2 Generating Virtual Sensor Data

How to generate realistic sensor data during simulation. Discuss complexity and benefits regarding generating raw data versus preprocessed information.

#### 3.2.1 Generating Data from Virtual Environment

Using maps of sea and coast line, information of other simulated agents and 3D models of installations in sea (for example harbors) to decide what the sensors "see".

### **3.2.2 Raw vs Preprocessed Sensor Data**

Complexity and benefits regarding generating raw data versus preprocessed information.

# **Chapter 4**

## **Simulator - HIL interface**

### **4.1 Physical Interface**

### **4.2 Software Interface**

#### **4.2.1 Necessary Exchange of Information**

#### **4.2.2 Message Protocol**

# **Chapter 5**

## **Logging and Visualization of Simulation**

### **5.1 Logging**

### **5.2 Visualization**

### **5.3 C++ example?**

## **Chapter 6**

# **Use of Model in Autonomous Testing Environment (ROS)**

# **Chapter 7**

## **Other Agents and their Behavior as Part of Simulated Environment**

### **7.1 Possible Agents**

#### **7.1.1 Ships**

#### **7.1.2 Small Boats**

### **7.2 Pros and Cons of Agents Behavior**

#### **7.2.1 Reactivity?**

#### **7.2.2 Predictability**

#### **7.2.3 Possibility of Repeating Scenario**

# **Chapter 8**

## **Summary and Recommendations for Further Work**

### **8.1 Summary and Conclusions**

### **8.2 Discussion**

### **8.3 Recommendations for Further Work**



# **Appendix A**

## **Acronyms**

**FTA** Fault tree analysis

**MTTF** Mean time to failure

**RAMS** Reliability, availability, maintainability, and safety

# **Appendix B**

## **Additional Information**

This is an example of an Appendix. You can write an Appendix in the same way as a chapter, with sections, subsections, and so on.

### **B.1 Introduction**

#### **B.1.1 More Details**

# Bibliography

Lundteigen, M. A. and Rausand, M. (2008). Spurious activation of safety instrumented systems in the oil and gas industry: Basic concepts and formulas. *Reliability Engineering and System Safety*, 93:1208–1217.

Rausand, M. (2014). *Reliability of Safety-Critical Systems: Theory and Applications*. Wiley, Hoboken, NJ.

Rausand, M. and Høyland, A. (2004). *System Reliability Theory: Models, Statistical Methods, and Applications*. Wiley, Hoboken, NJ, 2nd edition.