Autonomous vehicles

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AUTONOMOUS VEHICLES

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AUTONOMOUS VEHICLES

AUTONOMNA VOZILA

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Luka Perman ______________________________

SUMMARY

Autonomous vehicles are not science fiction anymore, autonomous technologies have been used in our daily lives for years now and it was only a matter of time before the cars started driving without a driver, the ships started sailing without a crew, or planes started flying without a pilot. This thesis will explore autonomous land, sea, and air vehicles and will focus on examining the technologies that make autonomy possible. There are different levels of autonomy and these levels will be clearly defined for each vehicle. This thesis will explore the pros and cons of autonomy and show examples of its everyday application. This thesis will explore the future of autonomy and will describe the "roadmap" for each vehicle to the point where it becomes fully autonomous.

Keywords: Autonomous, vehicle, technology, car, plane, ship, levels, of, autonomy, future, land, sea, air.

SAŽETAK

Autonomna vozila više nisu znanstvena fantastika, već godinama koristimo autonomne tehnologije u svakodnevnom životu i bilo je samo pitanje vremena kada će automobili početi voziti bez vozača, brodovi započeti plovidbu bez posade ili avioni početi letjeti bez pilota. Ovaj će rad istražiti autonomna kopnena, morska i zračna vozila i usredotočit će se na ispitivanje tehnologija koje omogućavaju autonomiju. Postoje različite razine autonomije i te će razine biti jasno definirane za svako vozilo. Ovaj će rad istražiti prednosti i nedostatke autonomije i pokazati primjere njezine svakodnevne primjene. Ova će teza istražiti budućnost autonomije i opisat će "putokaz" za svako vozilo do te mjere da ono postane potpuno autonomno.

Ključne riječi: Autonomno, vozilo, tehnologija, auto, avion, brod, razine, autonomije, budućnost, kopno, voda, zrak.

Table of Content

1. INTRODUCTION

1.1. PROBLEM, SUBJECT, AND OBJECT OF THE RESEARCH

Autonomous technology is increasing its presence by the day, all the big companies are awestruck by its potential to change the world and to make a hefty amount of money by doing so. Autonomous vehicles pose a lot of obstacles that have to be resolved before the autonomous vehicles are free to roam free, the most important obstacles are technologies that have to be evolved to a point where they can be produced cheap and international laws concerning autonomous vehicles have to be defined.

Based on these facts, this thesis is covering the problem of implementation of autonomous vehicles, all the necessary steps, all the technologies concerning it, and important laws restricting their use. The subjects of research in this thesis are autonomous vehicles, and specifically autonomous land, sea, and air vehicles. The objects of this thesis are technologies and laws defining autonomous vehicles.

1.2. HYPOTHESIS

The hypothesis of this Master's thesis is to prove that autonomous vehicles are going to have a big impact on our future and that autonomous vehicles are here to stay and that they have the potential to change the world for the better. As always change is hard, and autonomous vehicles are far from being perfect but they are constantly being improved and redesigned in a way to improve our daily lives and allow safer, faster, and more efficient transportation.

1.3. PURPOSE AND GOALS OF THIS THESIS

The purpose of this Master's thesis is to define the autonomous vehicles, their history and to define autonomy levels concerning them and to provide an insight into the laws that are already in place and future laws that need to be implemented to regulate the use of autonomous vehicles.
This paper aims to provide answers to the following questions:

- What is an autonomous vehicle?
- How does an autonomous car drive, and what are the technologies allowing it?

- How does an autonomous ship sail, and what are the technologies allowing it?
- How does an autonomous aircraft fly, and what are the technologies allowing it?
- What are the pros and cons of autonomous vehicles?
- What are the laws concerning autonomous vehicles?
- Where do autonomous vehicles stand today and when can they be expected?

1.4. SCIENTIFIC METHODS

The process of writing this Master's thesis is based on a methodological approach. Scientific methods used for writing and formulating the results are the method of analysis and synthesis, the method of induction and deduction, the graphic method, the statistical method and the method of description.

1.5. STRUCTURE OF THE THESIS

Structure of the Master's thesis "AUTONOMOUS VEHICLES" is divided into six chapters:

INTRODUCTION is the first chapter in this thesis. This chapter explains the problem, subject, object, hypothesis, purpose, and goals of the thesis and the scientific methods used in the thesis.

The second chapter is named AUTONOMOUS LAND VEHICLES. In this chapter autonomous cars will be looked into, the technology behind them will be explained and the six autonomy levels concerning them will be defined and laws concerning them will be examined.

The third chapter is named AUTONOMOUS SEA VEHICLES. In this chapter autonomous ships will be examined, and the technology behind them and their dynamic autonomy will be explained. Their current laws will also be examined and future necessary law changes will be looked into.

The fourth chapter is named AUTONOMOUS AIR VEHICLES. In this chapter autonomous aircraft will be examined, the technology behind them will be explained and their categories will be defined and also the legislation concerning them will be looked into.

The fifth chapter is named THE FUTURE OF AUTONOMOUS VEHICLES. In this chapter, the future implications of autonomous vehicles will be defined and the impact of the COVID-19 pandemic on autonomous technology will be studied.

In the last chapter, CONCLUSION will give a summary of the overall thesis.

Literature used to write this thesis and tables, figures, schemes, charts, and table of abbreviations used in this thesis will be listed on the last few pages.

2. AUTONOMOUS LAND VEHICLES

Two major factors that led to the development of electronic control in cars were the invention of the integrated circuit and the invention of microcomputers. Microcomputers had a major impact on creating autonomous technology because they are considered to be the "brains" of operation in all kinds of vehicles today. As an example, the cruise control mode works in a way that the driver inputs the desired driving speed, and then the computer does the calculations between the desired speed and the actual speed and adjusts the driving speed according to the desired speed.

A vehicle is considered fully autonomous when the computer replaces the human driver and does everything a human driver would do and does that at the same quality or even better than a human. The final product of this technology would come down to a human entering a vehicle, inputting the desired location, and then the vehicle would autonomously and efficiently drive the human to the desired location without the need for human intervention. During the ride the computer would do all the necessary calculations, adapting to the road conditions, avoiding all kinds of obstacles in real-time, and adjusting the speed according to the legal limits.

To enable this complete autonomous technology the vehicle would rely on different kinds of technology for its trip to the final destination. The vehicle should be able to detect the right lane for overtaking or taking the right exit, it should be able to spot the difference between alive and solid objects on the road and predict the path of other drivers or pedestrians on the road. To accomplish this, the vehicle will be equipped with different kinds of short and long-range sensors and lidars and radars.

It is believed that autonomous vehicles have the ability to restructure the transportation industry, lower or completely eliminate the number of land, air, and sea accidents, and to provide efficient transportation and with that lowering the pollution by a great margin with the implementation of electric motors.

2.1. AUTONOMOUS VEHICLES THROUGH HISTORY

The first appearance of a self-driving vehicle was at the Futurama exhibition hosted by Norman Bel Geddes from the carmaker “General Motors” at the 1939 World's Fair. There were shown electric cars with circuits built into the pavement, and they were radio-controlled.

Around 1980 the Mercedes-Benz robot van project by Ernst Dickmanns could reach a speed of 100 km/h on streets without traffic. The European Commission shows interest in such innovative technology and starts funding the Eureka PROMETHEUS project regarding autonomous vehicles in 1987.-1995. The funding amount was EUR 800 million.[1]

Almost at the same time, in 1980, the DARPA-funded ALV (Autonomous Land Vehicle program) in the USA built the first vehicle that drove at a speed up to 30 km/h using radar and different sensors.[2]

In 1987, HRL Laboratories introduced the first autonomous vehicles made for difficult terrain. At a speed of 3 km/h, the vehicle passed more than 600 meters on difficult terrain with dense vegetation, big slopes, and rocks.[3]

In 1994, two semi-autonomous vehicles, Vita-2 and VaMP drove on the motorway near Paris more than 1,000 kilometers, although semi-autonomously, they drove at speeds up to 130 km/h with some human intervention.[4]

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[1] https://media.daimler.com/marsMediaSite/en/instance/ko/The-PROMETHEUS-project-launched-in-1986-Pioneering-autonomous-driving.xhtml?oid=13744534(3.07.2020)
[2] https://www.wired.com/brandlab/2016/03/a-brief-history-of-autonomous-vehicle-technology/(3.07.2020)
[3] https://medium.com/@davidrostcheck/the-self-driving-car-from-1994-fb1ec617bd5a(3.07.2020)
[4] https://www.guideautoweb.com/en/articles/37193/the-first-autonomous-cars/ (03.07.2020)

Picture: 1. VaMP 1994

Source:https://medium.com/@davidrostcheck/the-self-driving-car-from-1994-fb1ec617bd5a (03.07.2020)

In 1995, the autonomous Mercedes-Benz S-Class drove from Munich to Copenhagen (1,600 km) and back using the software in computers that analyzed the road and worked in real-time. On the German motorway, it reached speeds above 175 km/h with as much as 95% autonomous driving. In only 9 km of the journey human intervention was needed. 158 km were covered with no human intervention despite it being a research vehicle with no promises of long-term reliability.[5]

Argo project was launched in 1996. by Alberto Broggi of the University of Parma. Argo project based itself on enabling a modified Lancia Theme model to follow colored markings on the road. A journey of 2000 km over 6 days on the highways of northern Italy was the highlight of the project achieving an average speed of 54 km. Stereoscopic visual algorithms and 2 black and white cameras were used to "understand" its environment.[6]

The US government funded 3 military efforts in order to try and achieve autonomy knows as Demo 1, Demo 2 and Demo 3. Demo 3 showed its ability by driving over difficult terrain and avoiding obstacles.

[5] https://www.autoevolution.com/news/mercedes-benz-had-autonomous-cars-back-in-1985-before-it-was-cool-93769.html (03.07.2020)
[6] http://www.argo.ce.unipr.it/argo/english/flyer_en.pdf(03.07.2020)

In 2010, VisLab led the VisLab Intercontinental Autonomous Challenge which was a 13,000 km long test for autonomous vehicles. The journey was from Italy to China and four driverless electric vans completed the journey and arriving at the Shanghai Expo on October 28, 2010. That was the first intercontinental route with autonomous vehicles.[7]

A little over 14 years ago, at an abandoned air force base near Los Angeles, the Urban Challenge event was held. Driverless cars drove through traffic to win the race. It was the third and final autonomous vehicle competition by DARPA.[8]

At that time, DARPA was trying to create autonomous cars but with no luck, their efforts had no results, so they organized a competition and invited the whole world to create an autonomous vehicle that can drive through the Mojave Desert of California, and win a million-dollar reward. This challenge was called the Grand Challenge.[9]

The teams took scavenged sensors and old computers from a dump, wrote a “dirty” code, and welded their hardware on the vehicles hoping the cars would drive 142 miles through the sand, gravel, and dirt of the Mojave Desert. The most successful vehicle achieved only 7 miles. Most vehicles ended on their roofs, were damaged beyond repair, or didn’t even move from the start line. However, the race, no matter the results, created a community of enthusiasts who believe autonomous vehicles are not an elusive endeavor.

As expected the teams from 2004. Grand Challenge returned to prove that self-driving cars are possible. Five vehicles managed to reach the finish line and the race was called a success. By the time of the third race in 2007. called the “Urban Challenge” vehicles not only avoided obstacles successfully and maintained a perfect trajectory on the road but also followed traffic laws, mastered parking, and changed lanes.

In 2009, a team of DARPA Challenge veterans was hired by Google for its self-driving project. Within two years a system that could handle some of California’s toughest roads was built. Elon Musk announced that Tesla would implement self-guidance in their vehicles a few years later.

[7] https://www.inderscience.com/info/inarticle.php?artid=51250 (03.07.2020)
[8] https://www.darpa.mil/about-us/timeline/darpa-urban-challenge (03.07.2020)
[9]https://www.darpa.mil/news-events/2014-03-13(03.07.2020.)

Meanwhile, companies like Uber and Lyft have weakened the link between driving a car and owning a car.

After a few years, autonomous technology has reached its peak for experimentation and research, no car manufacturer can ignore the fact that the time of self-driving cars is coming. Companies like General Motors, Ford, Nissan, Mercedes, Tesla, and many others have started investing billions in developing their own autonomous technology and trying to implement it in their vehicles. Hundreds of smaller start-up companies are rushing to offer larger companies improved tech like cameras, radars, sensors with competitive prices. The race has begun.[10]

2.2. LEVELS OF AUTOMATION

Researchers forecast that by 2025 there will be approximately 8 million autonomous or semi-autonomous vehicles on the road. Before merging onto roadways, self-driving cars will first need to progress through six levels of driver assistance technology advancements.[11]

The Society of Automotive Engineers (SAE) defines six levels of driving automation starting from 0 (fully manual) to five (fully autonomous). These levels are adopted by the U.S. Department of Transportation. [12]

• Level 0 (No Driving Automation)

Most of the vehicles today are Level 0. These vehicles are manually controlled and have no driver assistance. Some systems help the driver like the emergency brake system, but since it does not drive the car it is not considered as automation.

• **Level 1 (Driver Assistance)**

[10] https://www.wired.com/story/guide-self-driving-cars/(03.07.2020)
[11] https://www.abiresearch.com/press/abi-research-forecasts-8-million-vehicles-ship-sae-level-3-4-and-5-autonomous-technology-2025/ (03.07.2020.)
[12] https://www.synopsys.com/automotive/autonomous-driving-levels.html (08.07.2020)

These vehicles are equipped with one bareboat automation technology like “cruise control”, however that only helps keep a safe distance between a car in front and the driver still has to take care of braking and steering.

• Level 2 (Partial Driving Automation)

In this category steering direction and the speed can both be vehicle-controlled, however the driver still is sitting in the driver's seat and has to keep an eye out.

• **Level 3 (Conditional Driving Automation)**

Level 3 vehicles can detect the environment surrounding them and are capable of making decisions, like avoiding obstacles or accelerating past a vehicle. They still require full human override and the driver must be prepared to take control at any point.

• **Level 4 (High Driving Automation)**

Level 4 vehicles are the first category with real self-driving capabilities. They can be fully autonomous within a limited area and can reach a top speed of 50 km/h but need human intervention in difficult road conditions. This is perfect for city ridesharing platforms where there is a lot of traffic and speeds over 50 km/h are rare.

• **Level 5 (Full Driving Automation)**

Level 5 vehicles are peak autonomy, the final product, according to the plans they won't even have a steering wheel inside or pedals. They will be able to bring the person anywhere with the only human input required being the typing of the desired location into the computer. These vehicles are already being tested across the world however the biggest obstacle for this technology is the Law considering autonomous vehicles.

2.3. DRIVER ASSISTANCE

Driver assistance systems do not necessarily form a completely autonomous vehicle but are links of a chain that are necessary to create one. Driver assistance technologies function as components of an autonomous vehicle, in the meantime they are sold as gadgets that assist and help drivers.

2.3.1. Sensorial-informative mechanisms

Sensorial-informative mechanisms are systems that inform the driver of events that could have passed unnoticed by the driver, for example:

• Lane Departure Warning System (LDWS).

• Rear-view alarm, to help detect and avoid obstacles.

• Visibility aids for the driver, that help see blind spots around the vehicle and enhanced vision systems like lidars and radars and night vision.

• infrastructure-based systems that send real-time information to the vehicle and inform the driver on upcoming events or problems on the road or weather

- **Lane departure warning system:**

A lane departure warning system is designed to inform the driver when the vehicle begins to move out of its lane. The warning can be audible, visual in the form of blinking light in the dashboard, or even vibrations on the steering wheel. In some vehicles where the lane-keeping system (LKS) is present the vehicle will even take steps to return the vehicle in its lane if the driver for some reason wasn't able.[13]

[13] https://www.safercar.gov/Vehicle+Shoppers/Safety+Technology/ldw/ (08.07.2020)

The first lane departure warning technology was introduced in Europe for Mercedes Actros commercial trucks in 2000 and is available today in most trucks sold in Europe.

Lane warning/keeping systems rely on different technologies to provide accurate corrections to the vehicle's path. Video, infrared and laser sensors mounted on the vehicle, under the vehicle, or within the vehicle front are able to detect the vehicle moving from its lane accurately and send the warning to the driver or in the lane-keeping system case, they immediately correct the vehicle if no blinkers are turned on.

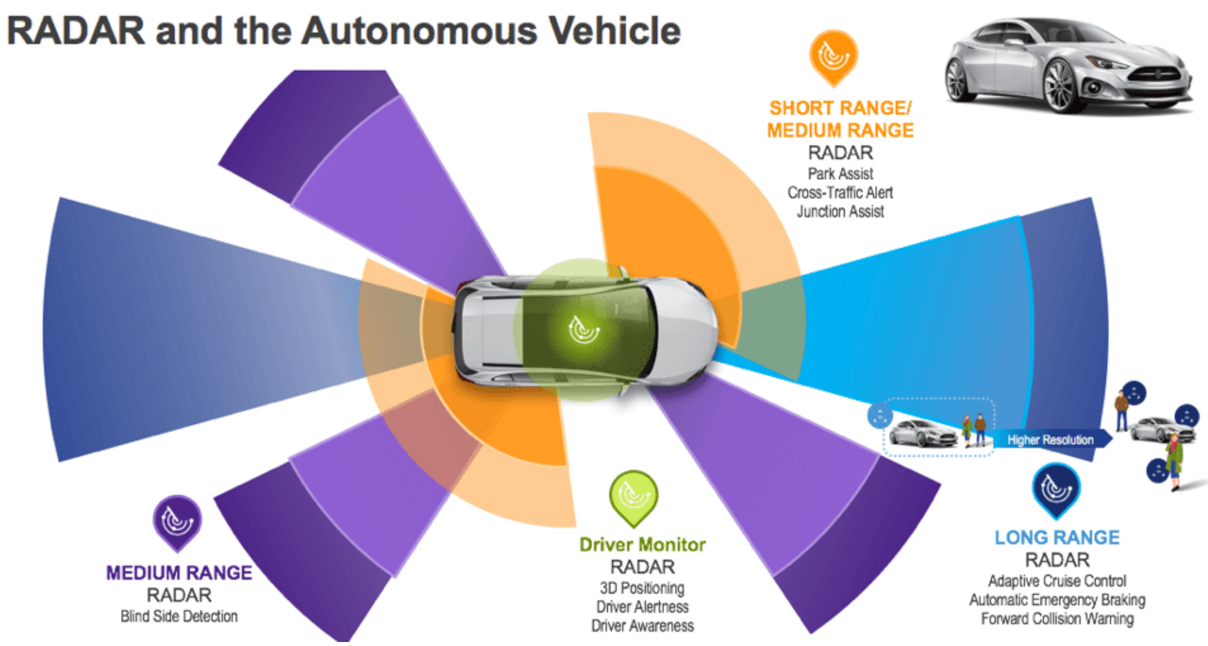
- **Radar:**

Radar technology allows object detection in different ranges and it uses electromagnetic waves to achieve that. Using these radio waves it can detect the range, direction of an object, its speed and is able to distinguish stationary and moving objects. It is used in all ranges of vehicles, from cars to submarines and planes.[14]

Radars emit radio waves (radio signals) in desired directions, when these waves come in contact with an object they are reflected or scattered in many directions. They reflect especially well by metal, seawater, and wetlands. After the signals are reflected they travel back to the transmitter, the transmitter then knows the location of the object and when the object moves there are small changes in the frequency and so it can detect the distance, size, and direction of the reflected object, this is called the Doppler effect.

[14]https://www.everythingrf.com/community/automotive-radarbasics#:~:text=Automotive%20radars%20are%20used%20to,'%20distance%2C%20speed%20and%20direction. (10.07.2020)

Picture 2: Radar on an autonomous vehicle and the technologies relying on it



Source: https://semiengineering.com/here-comes-high-res-car-radar/ (10.07.2020.)

- **Wireless vehicle safety communication:**

A vehicle wireless safety communication system is used to send and receive real-time information about the road condition, potential hazards, weather, and important news. It works by exchanging information with road infrastructure and other vehicles. The information can be sent using short-range radio links or wireless connection.[15]

This technology is going to be made possible by installing wireless units in vehicles and road infrastructure like traffic lights and emergency call boxes alongside the road. Data is also possible to be sent to longer ranges by utilizing multi-hop paths. Multi-hop paths work by utilizing other vehicles or road infrastructure to "catapult" information to longer distances, the perfect example of this is in the case of a road accident and then the information is able to travel from car to car all the way to the end of the traffic jam and informing all the drivers of the situation in the

[15] https://semiengineering.com/here-comes-high-res-car-radar/ (10.07.2020.)

process. Another example is in case of bad weather, the vehicle can receive a warning and show it to the driver in the dashboard so the driver can adapt to the road conditions on time.

The end goal of this technology is to increase vehicle efficiency to save fuel and reduce pollution. The way it is going to be able to achieve that is by connecting multiple vehicles like trucks in a convoy to move at the same time like a single unit, also in traffic jams, all vehicles will move simultaneously and by doing that traffic jams will be reduced by a large margin.

- **Motion detector:**

A motion detector works by using a physical mechanism or an electronic sensor that quantifies motion which will be sent to other devices that can alert the driver of objects moving into the vehicle detection range. Most motion detectors work up to 15-25 meters which is ideal in a car for parking or avoiding a collision.

The potential of this technology is yet to be fully known, however many manufacturers have acknowledged its potential, for example, Mercedes Benz is utilizing it in its newest 2021 S class model by not only helping with the parking and obstacle avoidance but by using it to lighten the impact in case of a crash. To achieve that in case of a side impact the vehicle detects a car on the collision course with the vehicle and then lifts the side where the car is going to hit to offer increased protection and to lighten the impact and preserve human life. This is only one example of how this technology is utilized to help and protect the driver and the passengers.[16]

[16] https://www.caranddriver.com/news/a33864734/2021-mercedes-benz-s-class-safety-features/ (11.07.2020)

There are basically three sorts of sensors utilized in the motion detectors spectrum:[17]

Passive infrared sensor (PIR)

Detects heat, more specifically body heat, and sends signals to notify the computer.

Ultrasonic (active)

Works by sending pulses and then measures the reflections of the moving objects.

Microwave (active)

The sensor sends out microwave pulses and measures the reflections off a moving object. It works using the same technology as a police radar gun.

2.3.2. Actuation-corrective

These systems are designed to modify and adapt the driver's instructions to have them executed more efficiently. The most popular and widespread is the anti-lock braking system (ABS) which helps the driver from losing traction while breaking, however, ABS is not considered an autonomous technology because it is not directly involved in vehicle decision making. ABS is considered a driver assistance technology and it is a crucial component of every autonomous vehicle.

• Anti-lock braking system (ABS) works by preventing the brakes from locking and losing the traction with the road while the driver is braking. This technology aims to shorten stopping distances and most importantly it allows the driver to have the control of the vehicle and steer while braking.

• Traction system (TCS) works by the vehicle onboard computer detecting a wheel spinning faster/slower than the other wheels and then breaking/accelerating it to match the other wheels. This prevents oversteer and understeer and lessens the probabilities of wheel spin happening.

• Four-wheel drive (AWD) is a technology that enables vehicles to distribute power to all four wheels, which helps increase road traction and lessens the probabilities of wheel spin. Fuel

[17] https://www.safewise.com/resources/motion-sensor-guide/ (11.07.2020)

consumption is higher and therefore newer vehicles have the ability to turn the four-wheel-drive off to conserve fuel and give the driver the ability to turn it on when the road conditions require it.

• Electronic stability control (ESC) works by utilizing different sensors across the vehicle to detect a loss of control of the vehicle and then the onboard computer quickly calculates the necessary actions to take to regain the control of the vehicle and executes them. The vehicle is able to reduce power and brake individual wheels to regain control.

- **Anti-lock braking system (abs):**

An anti-lock braking system (ABS) works by using sensors that are located in each wheel that detect when a wheel is going to lock up and stop moving, then it briefly releases that wheel. The system works so that it constantly monitors the wheels and allows just enough braking force to avoid wheel lock-up thus increasing traction and safety.[18]

ABS works especially well on dry and wet surfaces where it decreases the stopping distance by a large factor but on not solid surfaces like snow or gravel it increases the stopping distance but helps keep vehicle control.

Since initial widespread use in production cars, anti-lock braking systems have evolved considerably. Recent versions not only prevent wheels from locking but also electronically control the front-to-rear brake bias. This function, counting on its specific capabilities and implementation, is understood as electronic brakeforce distribution (EBD), traction system, hand brake assist, or electronic stability control (ESC). A typical ABS includes a central electronic control unit (ECU), four-wheel speed sensors, and a minimum of two hydraulic valves within the brake hydraulics. The ECU constantly monitors the rotational speed of every wheel; if it detects a wheel rotating significantly slower than the others, a condition indicative of impending wheel lock, it actuates the valves to scale back hydraulic pressure to the brake at the affected wheel, thus reducing the braking force on that wheel; the wheel then turns faster. Conversely, if the ECU detects a wheel turning significantly faster than the others, brake hydraulic pressure to the wheel is increased therefore the braking force is reapplied, slowing down the wheel. This process is repeated continuously and may

[18] https://www.digitaltrends.com/cars/what-does-abs-mean-on-a-car/ (11.07.2020)

be detected by the driver via pedal pulsation. Some anti-lock system can apply or release braking pressure 16 times per second.[19]

- **Electronic brakeforce distribution:**

Electronic brakeforce distribution (EBD) is a technology that calculates the necessary force that has to be applied to each wheel individually to ensure maximum vehicle control depending on the speed, steepness, road conditions, and weather. By applying individual breaking power the vehicle is able to break more efficiently and the vehicle has a shorter braking distance. EBD primarily focuses on the front wheels by applying more braking power to the front wheels and less braking power to the rear wheels to avoid wheel lock and skidding, however it varies from vehicle to vehicle.

- **Traction control system:**

Traction control system (TCS) is a system that activates if the wheels lose traction and begin to spin. It works by actuating brakes or reducing the throttle to regain traction. TCS is usually a secondary function of the ABS, however it does not have to be.

The vehicle regains traction by suppressing the spark or the fuel supply to at least one cylinder, it can break one or more wheels and in turbocharged vehicles, the boost control can reduce the boost, and by doing that reduces the engine power.

- **Four-wheel drive:**

Four-Wheel-Drive (AWD) is a technology that enables the distribution of power to all or just two wheels, which increases the traction and reduce the chance of wheel spin.

AWD or 4x4 is a four-wheeled vehicle that allows all wheels to receive torque from the engine simultaneously. It is widely believed that only off-road vehicles benefit from all-wheel

[19] https://www.brainkart.com/article/Anti-lock-braking-system-(ABS)_5068/ (11.07.2020)

drive, however, all-wheel drive is beneficial for all kinds of vehicles. AWD allows vehicles to have more control and better traction.

- **Electronic stability control:**

Electronic Stability Control (ESC) is a technology that utilizes various sensors to intervene when the on-board computer senses the possibility of losing traction or control. When that happens the car's control unit can brake individual wheels or reduce the engine power to stop the wheels from understeering or oversteering. According to IIHS and NHTSA, one-third of fatal accidents could have been prevented by this technology.[20]

During normal driving, ESC constantly calculates in the background the vehicle's direction and the desired driver direction, in case the vehicle senses a loss of control it automatically tries to regain control by braking individual wheels asymmetrically countering the skid and regaining control.

A downside of ESC is that it corrects skidding much faster and more effectively than the human driver, often even before the driver senses the loss of control. This had led to concerns that ESC could cause drivers to become overconfident in their driving skills, and cause them to constantly risk losing control of the vehicle. A solution to this is that ESC systems inform the driver when the ESC prevented the car from losing control so that the driver knows that he is pushing the vehicle to its limits. This usually happens with a light turning on in the dashboard and signalizing that ESC is activated. All ESC manufacturers emphasize that the system is not a performance enhancement and that drivers should not rely on it to keep the vehicle always in control and that safe driving practices should be respected. However, drivers should not rely on ESC while driving to save the vehicle from reckless maneuvers and severe hydroplaning but take it as a last resort function.

[20] https://www.iihs.org/topics/advanced-driver-assistance (11.07.2020)

- **Power steering:**

The term power-assisted steering is typically used to describe a technology that helps the driver to easily turn the steering wheel, even when the vehicle is not moving.[21]

Turning the steering wheel in a vehicle that does not have power-assisted steering requires much more force than a driver could find comfortable, that is especially true when the vehicle is parked or moving at a slow speed. The required force to turn the wheel depends on the length and the weight of the vehicle, so it is very noticeable on larger trucks. When a vehicle is equipped with power-assisted steering the driver barely feels any resistance which allows humans of all physique to comfortably drive the vehicle. The power-assisted steering system can be hydraulic (powered by a piston) or in cases of newer cars and trucks, it is electric (powered by an electric motor).

2.3.3. Systemic

Systemic software is a key technology of every autonomous vehicle no matter the autonomy level. Developing software that calculates, detects, and can drive the car without human input has been proven to be the biggest obstacle on the road to fully autonomous vehicles.

The first obstacle is to develop a system that detects other cars, humans, and obstacles. GPS and LIDAR systems are crucial for this operation since they can identify all objects moving or stationary across different ranges. The software must know what the object is, it has to distinguish a cyclist from a pedestrian to predict its movement pattern, also it had to distinguish a pedestrian waiting on a crossing to pass the road and a tree beside the road. In order to achieve a high accuracy level the software is put through millions of simulations and the vehicles already have millions of hours on the road in the real world, so it is only a matter of time when accuracy won't be a problem. A perfect example of machine learning is implemented in the Tesla vehicles. Almost every month the vehicles get a software update where new autonomous algorithms and simulation results are uploaded in the vehicle computer and the vehicle gets smarter and can handle more difficult road situations with every update.[22]

[21] https://www.caranddriver.com/features/a27888229/power-steering/ (11.07.2020)
[22] https://www.tesla.com/support/autopilot (12.07.2020.)

Thanks to the systemic software automatic parking is not science fiction. There are already a dozen of car models from different manufacturers that offer cars with autonomous parking features. The autonomous parking technology relies on a set of sensors that surround the car in a 360-degree angle and the on-board computer calculates the necessary actions the vehicle has to take to move from the current vehicle position into the parking space. After the calculations are done it all comes down to the vehicle performing the scheduled actions. It is important that the vehicle continues to monitor its surroundings while executing the parking maneuver and adapts to the new situations, that’s where lidars and radars are important in order to detect incoming pedestrians and other vehicles before they come into close proximity. Not every car has an autonomous parking feature but what almost every new car today has are parking sensors built into the car that are able to assist the driver while parking that can detect close objects and notify the driver of their proximity. These sensors can be front or back only, they can also be mounted on the sides and some vehicles have sensors all around the vehicle.

2.4. PROS AND CONS OF AUTONOMOUS LAND VEHICLES

Benefits of autonomous land vehicles:

- REDUCED ACCIDENTS

According to the USDOT website: "With 94 percent of fatal vehicle crashes attributable to human error, the potential of autonomous vehicle technologies to reduce deaths and injuries on our roads urges us to action."[23]

With human error out of the equation and with the software becoming more advanced by the day self-driving cars should get “smarter” every day which will lead to a drastic decrease in road accidents.

[23] https://www.transportation.gov/(12.07.2020)

- REDUCED TRAFFIC CONGESTION

Americans currently spend more than 6.9 billion hours a year sitting in traffic, according to the American Society of Civil Engineers.[24]

The idea is that even with only 5% of vehicles being automated the stop and go waves caused by human behavior while driving can be eliminated. As the percentage of autonomous vehicles increases in theory that should also increase the traffic flow, vehicles will start sooner, brake far less, there will be no cars bottlenecking the road.

It is also important to point out that traffic jams and road accidents are connected since most traffic jams are caused by road accidents. So by eliminating road accidents, huge traffic jams that are parts of our daily lives are eliminated also.

- REDUCED CO2 EMISSIONS

The reduction in congestion will most likely result in a reduction of CO2 emissions as well. In addition, the Future of Driving report from Ohio University states: "Since the software will drive the car, the modern vehicle can now be programmed to reduce emissions to the maximum extent possible. The transition to the new-age cars is expected to contribute to a 60% fall in emissions."[25]

- INCREASED LANE CAPACITY

Different research papers show that the implementation of autonomous vehicles could increase the highway capacity by 100% and increase the travel speed by 20%. This is even without counting the possible vehicle “platooning” which all the cars could be grouped and act as a single unit, avoiding distance between the vehicles and all the cars would start and stop at the same time. Human drivers tend to leave a lot of space between them and other cars, which is great because it

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[24] https://www.infrastructurereportcard.org/roads/conditions-capacity/ (12.07.2020)
[25] https://onlinemasters.ohio.edu/blog/the-future-of-driving/(12.07.2020)

is safer, however when there are autonomous vehicles in question that is wasted space since autonomous vehicles do not need that “extra breathing room” on the road.

- LOWER FUEL CONSUMPTION

Autonomous vehicles can increase fuel efficiency by efficiently driving the vehicle, accelerating and braking only when necessary, also vehicle platooning allows for driving with a slower maximum speed (which is more fuel-efficient) but increased effective speeds since there are no traffic jams and the whole platoon almost moves like a train.

- TRANSPORTATION ACCESSIBILITY

One of the most important benefits of autonomous vehicles is that anyone will have the luxury of complete mobility. Senior citizens won't have to rely on cramped public transportation or ask someone to drive them somewhere or walk long distances. They will be able to use an autonomous vehicle like anyone else. The same goes for handicapped people, they will have complete mobility which will be unbelievable since they are completely dependent on other people today.

Ridesharing will have a major role in the upcoming future. In theory, while you are home you can lend your vehicle out to go pick some people up and drive them to their destination and the people will be able to pay directly to the vehicle. This means your vehicle will be able to earn money while you are not using it. Of course, other people will do the same so the market for ridesharing will be big, but still, the vehicle will be able to make enough to cover its expenses.

“The aging of the population converging with autonomous vehicles might close the coming mobility gap for an aging society,” said Joseph Coughlin, the director of the Massachusetts Institute for Technology AgeLab in Cambridge, quoted in an article in the New York Times.[26]

[26] https://www.nytimes.com/2017/03/23/automobiles/wheels/self-driving-cars-elderly.html(14.07.2020.)

- REDUCED TRAVEL TIME AND TRANSPORTATION COSTS

“AVs may cut travel time by up to 40 percent, recover up to 80 billion hours lost to commuting and congestion, and reduce fuel consumption by up to 40 percent. These cost/time-saving benefits are expected to be worth about US$1.3 trillion in the country. Other potential cost-saving domains include reduced manpower — drivers and law enforcers," according to a report from KPMG.[27]

- MORE EFFECTIVE AND AFFORDABLE TAXIS.

The Future of Driving report from Ohio University states that with autonomous taxis, "The waiting time for a cab will come down from the average five minutes today to just 36 seconds. The cost of a ride too will come down to just $0.5 per mile in a driverless car."[28]
Since every autonomous vehicle will be able to be used for ridesharing, the ridesharing market will be huge. Mobility will be cheap, reliable and everyone will be able to afford it. It is likely to happen that ridesharing becomes so efficient that many people will choose not to have a car and yet to be driven every day constantly.

Picture 3: Waymo Autonomous taxi company which served over 100,000 customers

[27]https://home.kpmg/xx/en/home.html (14.07.2020.)
[28]https://onlinemasters.ohio.edu/blog/the-future-of-driving/ (14.07.2020.)

Source: https://www.bloomberg.com/news/articles/2019-12-05/waymo-s-autonomous-taxi-service-tops-100-000-rides

- MORE EFFICIENT PARKING

Since the vehicles will be autonomous it is possible that city centers won't be used for parking anymore, there can simply be parking outside of the city where the vehicle can go park itself after it takes you to your desired destination. And when a person is finished he can just notify that vehicle and the vehicle can come to pick the person up.

According to different studies, a lot of people won't own a car since ridesharing will be so popular so there won't be a huge demand for parking so there will be easier to find a parking space anywhere.

Autonomous vehicles are equipped with 360 degrees sensors in all directions which allow the vehicle to park accurately down to millimeters. Autonomous vehicles will be able to stack closely one to another on parking spaces since there will be no need for room for a person to get in, the car will simply turn on and come pick you up.

Cons of autonomous land vehicles:

- HACKING THREAT

When handling technology there is always a threat from hacking. Cyber-security will have a major impact in the future autonomous vehicles and they will have to be well defended against cyber-attacks.

Errors and glitches are also a cause for concern. Every software encounters them from time to time, which is normal as long as the vehicle knows what to do in case of loss of control. It can be as simple as notifying the driver to take over or the vehicle can find a safe space to stop and recalibrate its systems.[29]

[29] https://eu.freep.com/story/money/cars/2020/01/08/car-hacking-technology/2841847001/ (14.07.2020)

- MORAL DILEMMA

Different situations can happen on the road, and sometimes there is no right choice, it is going to happen that someone runs in front of the vehicle out of nowhere and the vehicle will have to make a decision what to do.

Autonomous vehicles are programmed to prioritize the driver's life in all scenarios and if it has to endanger the driver's life it will rather hit a person on the road. This raises ethical questions and accidents will happen where an autonomous vehicle will kill someone, however there will be barely any cases in comparison to today where 1.3 million people die because of road-related accidents, however, autonomous vehicles will be more strictly judged and criticized because a computer was responsible for someone's death.[30]

- LOSS OF JOBS

A lot of jobs rely on people driving vehicles, from the postmen, taxis to construction drivers, and truckers. These are all jobs that are in danger of becoming automated in the near future. That will generate conflicts in the interests and the government will have to handle it somehow, there are talks of implementing universal basic income for every citizen since most of the jobs today will be automated. Since the COVID-19 pandemic more are more governments are thinking about implementing the universal basic income scheme.[31]

- INTEGRATION TAKES A LOT OF TIME

Autonomous vehicles are a technology of tomorrow but not quite literally. They are here to stay, however, their implementation, if it wants to be done right, has to be gradual. Today there are thousands of companies researching and developing new technologies to ensure a safe and efficient autonomous future.

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[30] https://www.asirt.org/safe-travel/road-safetyfacts/#:~:text=Approximately%201.35%20million%20people%20die,resulting%20in%20long%2Dterm%20disabilities. (14.07.2020)
[31] https://www.marketplace.org/2020/04/06/universal-basic-income-was-a-fringe-idea-then-the-covid-19-pandemic-happened/ (14.07.2020)

The first steps are already being taken, in the next few years more and more autonomous vehicles with different levels of autonomy will share the roads with normal vehicles and their implementation will be gradual and planned. When the software for completely autonomous driving is ready at some point it will become standard equipment in vehicles since the goal is to remove human error out of driving.

- SOME PEOPLE LIKE TO DRIVE

Until self-driving cars become mandatory car lovers will have the freedom to drive the cars themselves. This can make a big impact on the percentage of autonomous car users and needs not to be taken lightly.

It is also very likely that there will be special lanes on highways for autonomous vehicles and for people driving the cars since people will want to drive from time to time and driving the car itself may be less efficient and riskier it may be the fastest way to get from point A to point B, depending on the road infrastructure and road conditions.

2.5. AUTONOMOUS LAND VEHICLES TODAY

Many companies are focusing on developing self-driving cars and hardware for autonomous vehicles of all kinds and some are further along in terms of real-world testing and practical experience than others.

As the development of self-driving cars progresses at a rapid clip, numerous companies have stated their intentions to develop and sell autonomous automobiles, but there's a difference between those companies that are simply "talking the talk" and companies that are literally test-driving their vehicles on public roads.[32]

[32] https://www.mes-insights.com/5-top-autonomous-vehicle-companies-to-watch-in-2020-a-910825/ (17.07.2020)

Top 5 Autonomous Vehicle Companies:

- WAYMO

Currently, the most widespread autonomous vehicle is the Alphabet's Waymo with 32 million kilometers driven in the real world and over 16 billion in the simulations.

Waymo utilizes all the technologies that are mentioned in this thesis to achieve autonomy and even brings some new technologies to the table like the smart microphones that detect sirens from emergency vehicles so the vehicle knows when it has to move out of its way.

At this moment in Phoenix, Arizona Waymo operates a fleet of level 4 autonomy taxis that have a driver in front for legal reasons but the car is mostly self-driven. Also, they are testing fully driverless level 5 autonomous vehicles.

Waymo is not only present in Arizona, recently they introduced the robot-taxis to Michigan and California to test the cars on different weather and road conditions.

Picture 4: Waymo taxi

Source: https://www.autonews.com/manufacturing/waymo-firms-plans-autonomous-car-assembly-plant-detroit (18.07.2020)

- GM CRUISE

General Motors' Cruise division has the world's second-largest autonomous fleet of 180 vehicles that are currently undergoing testing. So far they have driven over 1.6 million kilometers. The looks of this vehicle can deceive because it looks like a normal Chevrolet Bolt hatchback but under the hood apparently, over 40% of the parts are specially designed for autonomous driving.

According to GM they tend to help save millions of lives by reducing car crashes that happen because of human error, make transportation more accessible for everyone no matter their health and they want to give people time to other things instead of driving. This is a big statement but GM is absolutely certain they can make it happen.[33]

Picture 5: General Motors Cruise

[33] https://medium.com/cruise/cruise-self-driving-vehicles-cities-b8724cff6b5c (18.07.2020)

Source: https://www.therobotreport.com/gm-cruise-raises-1-15b-for-self-driving-cars/ (18.07.2020.)

- ARGO AI

The Ford Motor Company's Argo Ai startup is testing its 100 vehicles in six cities in the United States. Ford invested $1 billion in the company but still, it is technically an independent venture. However Ford isn't alone in this, Volkswagen also invested $2.6 billion. Currently, Argo AI is using Ford Fusions as test vehicles but that is likely to change in the future.

Argo AI's goal is to make transportation available to everybody, since not everyone has access to the luxury of owning a car. They want to make transportation affordable and reliable and with partnership from Ford and Volkswagen they are sure they are able to do it.

Picture 6: Argo AI

Source: https://www.carscoops.com/2019/06/ford-and-argo-ai-launch-their-third-gen-autonomous-fusion-hybrid/ (18.07.2020)

- TESLA

Tesla currently has the most vehicles on the road with advanced autonomy features. Tesla wants to do things differently than the other which is why Elon Musk swears that using Lidars is not the future however, every other car manufacturer disagrees, instead Tesla vehicles use an ultrasonic radar combined with 2D cameras to allow the vehicles to “see” their surroundings.

"Anyone counting on LIDAR is doomed. Doomed. [LiDAR is] expensive sensors that are unnecessary. It's like having an entire bunch of pricy appendices," Musk has said. "In cars, [LiDAR] is freaking stupid… as [Tesla AI director] Andrej [Karpathy] was saying, once you solve vision, it's worthless."[34]

What they are saying might be true because without the use of the Lidar they are the first company that managed to put so far over 730,000 vehicles on the road with various levels of autonomy and if it is to believe Elon Musk fully autonomous (level 5) vehicles should be on the road by the end of this year.

Picture 7: Tesla cybertruck

[34]https://techcrunch.com/2019/04/22/anyone-relying-on-lidar-is-doomed-elon-musk-says/ (19.07.2020.)

Source: https://electrek.co/2020/06/20/tesla-cybertruck-prototype-close-look-public-outing-pictures/ (18.07.2020)

- BAIDU

China's Baidu currently has more than 300 autonomous vehicles on the road having driven over 3 million kilometers in 23 cities. Baidu currently has 34 Robo-taxis operating and demonstrating its capabilities. Like Waymo China's Baidu has a driver present that has to intervene if there is a need. Baidu has said that they will be able to put fully autonomous vehicles on the road by 2025.

The market for autonomous vehicles is set to be worth over $500 billion by 2030. This has other Chinese car manufacturers fighting for the top spot which the Baidu currently has.

Picture 8: Baidu Apollo

Source: https://www.engadget.com/baidu-self-driving-car-computer-ready-081925160.html(18.07.2020)

3. AUTONOMOUS SEA VEHICLES

Technology is very hard to predict because of the fast research rate, 10 years ago the very idea that you could have all the capabilities of a today's smartphone in a pocket was considered impossible, and yet today phones are used for video calls with other parts of the world, home appliances are controled and even drones are operated by them, even Tesla cars have a feature which allows the user to summon the car (Tesla summon feature) so we should say that in some near future some aspects of of autonomous ships will be controllable with our computers or mobile phones.

The required technology for autonomous ships is already here, it is just a matter of putting it all together and making it work, so the question shouldn't be “will there be autonomous ships?” instead it should be “when are autonomous ships?”. Today autonomous ship software sailed over millions of hours in simulations because the legislation for the use of autonomous ships is not defined yet and real-world tests are hard to do.

In order to allow autonomous ships to start sailing, they have to be at least as safe as manned ships. Their main purpose will be to cut back human error and decrease operation costs without a need for a crew.

The benefits of autonomous ships are groundbreaking, without the need of a crew, there is also no need for living quarters on the ship, no need for cabins and food storage. The ships will be redesigned from the ground up without any need to focus on the crew. They ships will be cheaper, lighter and there will be more space for cargo which means the earnings will be bigger.

Autonomous ships will need human input, at least at the beginning therefore having a good connection between the vessel and the shore will be crucial. The data flowing between the shore computer and the ship's computer needs to have the highest priority of bandwidth in order to get the best connection possible. There can even be a range of satellites focusing on autonomous ships in order to secure a good connection in all weather conditions.

As there will be more and more autonomous ships sailing the seas the digitalization will create new kinds of shipping services that will offer more efficient pooling and different alliances will be formed. Online cargo services will have a major role and the competition is going to rise since new companies will fight for their share in the industry.

Of course, some types of cargo like project cargo or out of gauge cargo will still need increased human input because of the difficulty of the challenge. However, containerized cargo and container ships are likely to first be automatized since there are already online services for container shipping.

3.1. THE VISION BEHIND AUTONOMOUS SEA VEHICLES

Like with every artificial intelligence the job of the AI is to make human lives easier, the same goes for the shipping market and the ships. Autonomous technology can make transportation safer, increase ship efficiency, and relieve humans from spending months at sea.

If a study by Allianz is examiend, it is believed that between 75% and 96% of maritime accidents are caused by human error of some kind.[35] This is where autonomous and semi-autonomous ships come in. They have the potential to increase profits and at the same time make oceans safer and cleaner. Even if there is a crew on board, AI implementation with all the sensors and data will lead to better decision making for the crew.

Without a crew being on board, it is believed that a reduction of crew related costs can be made that reduce the total budget by 30%. One study projected that one autonomous vessel could save over $7 million over the span of 25 years from crew supplies, salaries, and fuel savings.[36]

3.1.1. Dynamic autonomy

In this Thesis, different levels of autonomy regarding the vehicle are being covered. The term LOA or levels of autonomy are often used to describe to what degree the machine can act on its own. Thomas Sheridan developed the probably the most well-known description for LOA, called the Sheridan Scale. It includes different levels with characteristics defining the level of autonomy from

[35] https://www.cbinsights.com/research/autonomous-shipping-trends/ (23.07.2020)
[36] https://safety4sea.com/key-advantages-and-disadvantages-of-ship-autonomy/ (23.07.2020)

the point where the human controls all aspects of the ship to a point where the Computer does everything ignoring the human.

LEVEL	**Table 1 – Sheridan levels of autonomy**
10	The computer does everything autonomously, ignores human
9	The computer informs human only if it decides so
8	The computer informs human only if asked
7	The computer executes automatically when necessary informing human
6	The computer allows human a restricted time to veto before automatic execution
5	The computer executes the suggested action if the human approves
4	Computer suggests a single alternative
3	Computer narrows alternatives down to a few
2	The computer offers a complete set of decision alternatives
1	The computer offers no assistance, human in charge of all decisions and actions

Source: made by the student according to https://humanrobotinteraction.org/autonomy/#:~:text=In%20Sheridan's%20scale%2C%20there%20is,assistance%3B%20human%20does%20it%20all (25.07.2020)

Different variations of this type of scale have been developed in the research. A common conclusion is that such scales may not be applicable to the entire spectrum of autonomous vehicles, but are most useful when applied to different subtasks of the autonomous machine.

This conclusion is highly relevant for autonomous vessels because the nature of the vessels will define the level of autonomy concerning it. Different kinds of cargo will have different kinds of autonomy. Simpler ship tasks will be executed by robots but as soon as ship tasks get complex a human intervention will be required.

Remote operated ships will follow this remotely operated approach, with the ship being mostly autonomous out on the open sea with the human operator intervening only in situations where that is necessary, for example on port approach, berthing, or going through narrow canals.

To further describe how an autonomous vessel would operate different parts of the voyage for a general cargo ship sailing between two ports will be examined:

- **Voyage planning and initiation**

Some things have to be taken into consideration when handling autonomous ships before planning the voyage. Autonomous vessels will rely on different communication technologies to ensure a stable connection is present as much as possible between the shore computer and the ship, in order to achieve that satellites and land-based communication devices will be used. However it is likely that some operation modes like full control of the ship will be bottlenecked by the satellite capabilities depending on the weather conditions or remote locations, therefore in order to have a good connection the main task in voyage planning is to make sure to plan a route where the ship will have the required connection level in order to ensure safe sailing conditions.[37]

In case the ship loses connection with the operator/shore the ship will need to have designed fallback procedures so when a loss of connection happens the ships know what to do. An example of this would be in case of the loss of connection the ship could return to the last point where the connection was available and then the operator can take a different route or see what was causing the connection issues.

An example of a fallback strategy would look like this: Asking the operator for manual control (if not possible) the ship would try to establish the connection (if failed) the ship would slow down and proceed to the previously set waypoint (if not possible) the ship would return to the last point where the connection was present (if failed) navigate to a set safe location). The voyage plan can be constantly changed and adapted thanks to the satellite link.

In order to ensure that the vessel is sea ready, a range of sensors will be placed on the ship so that the computer knows that all is well and ready before starting the voyage. Also while the vehicle is berthed the operator or the shore-based crew can make some final checks on the vessel to ensure that all is well.

- **Operation modes at open sea**

While the ship is out in the sea the normal autonomous mode will be in control of the ship. The operator will be able to check just the basic info like the heading of the ship, the speed, and

[37] https://www.sciencedirect.com/science/article/pii/S2405535214000035 (25.07.2020)

the ETA to the next waypoint. The operator will be able to intervene as soon as he sees that the ship needs instructions and he will be able to adapt waypoints based on the weather conditions. With the required interaction between the operator and ship being so small in this mode the operator will be able to operate different vessels at the same time. The idea is that as long as the vessels are using a high autonomy mode the mission is running successfully.

The idea of autonomous vessels is to keep the operator intervention at a minimal level and let the vessel bring its own decisions. In case the vessel senses a ship in front the vessel will place different waypoints in order to avoid the collision. The vessel will not ask the operator for intervention instead it will just notify the operator of the maneuver and then the operator can decide if he wants to intervene, or the operator can use a radio to notify the other vessel of the actions that his vessels are going to take to ensure all trouble is avoided.

It is certain that there will be situations where the vessel will request operator intervention, and operators need to be always ready for these situations. For example, in popular routes, there can be a huge amount of crafts in the way and the vessels will not be able to plan a safe avoidance plan, in this case, the vessel will send an urgent intervention request to the operator and request assistance if the operator is not available in case of bad connection the vessel has pre-planned fallback strategies.

- **Unmooring and maneuvering out of the harbour**

The mooring can be completely autonomous or it can be semi-autonomous depending on the dock infrastructure. If the system is completely operator controlled or it can be completely automaticaly executed by the vessel. When the mooring is semi-autonomous it means that the connections to the quay are automatic but the crew is required to secure the docking. It is not possible to use autonomous or semi-autonomous docking without the port being made to accept autonomous ships, changes in infrastructure need to be made. As more and more ships embrace autonomy so will the ports upgrade their infrastructure to be able to welcome autonomous vessels.[38]

[38] https://www.ship-technology.com/features/ports-autonomous-shipping/ (25.07.2020)

When the ship is maneuvering out of the harbor the operator can either have a direct remote control or supervisory control and only check if everything is going according to plan. In case there is a need for a pilot, he can just get in a call with the operator without the need for the pilot to come on board.

3.1.2. Port approach and docking

As the vessel comes in close vicinity to the port the connecting will be better which will always allow the operator to get control of the vessels if there is a need. Also, the vessel can utilize a land-based navigation system to approach the port as accurately and safely as possible and port workers can notify other ships of the autonomous vessel route.

3.1.3. The conclusion of dynamic ship autonomy

The conclusions of dynamic ship autonomy are:

- At least at the first phase of autonomous vessel implementation, the vessels will be a hybrid between the fully autonomous vessels and an operator-controlled one. As time progresses the autonomy level of the vessel will depend on the cargo and the vessel type.
- The technologies required to make ships autonomous are already present, however, the challenge is to combine the technologies in an affordable and efficient way in order to rival ships with a human crew. In order to achieve a high precision autonomous navigation and smart decision making, the vessels have to be thoroughly tested both in simulations and in the real world.
- In order to allow autonomous vehicles to sail between territorial and open waters existing laws have to be adapted and new laws concerning autonomous vessels have to be introduced. The question of liability needs to be clear and defined, when is it the operator's mistake and when is the vessel responsible (manufacturers will always protect themselves from liability).
- Autonomous vessels have to potential to completely redefine the shipping market, as the popularity of autonomous vessels rises, so will the competition. Companies that want to stay competitive will have to adapt to autonomous vessels and ports that want to accept autonomous vessels will have to upgrade their infrastructure.

3.2. TECHNOLOGIES FOR MARINE SITUATIONAL AWARENESS AND AUTONOMOUS NAVIGATION

In the last 10 years, the development of autonomous technologies for land, air, and sea vehicles has boomed. This reason for this is the growth in numbers of the research and development companies. A lot of start-ups and technology companies are competing to place the best products possible at a reasonable price at the market in order to get their share of the “cake”. Today a wide range of military-grade radars, lidars, and sensors are open for civil use which is accelerating the development of autonomous technology with the sensors being implemented in the vehicles to allow them to sense their surroundings. A point has been reached where the available technology is enough to make autonomous ships, it is just a matter of putting it together and testing it.

Autonomous ship navigation is made possible by sensor fusion. Sensor fusion is a term used to describe a range of different situational awareness systems combining their data to create a single accurate map of the vehicle's surroundings. In order for the vessel to be able to plan its routes and avoid obstacles or other vessels, the vessels need to have an accurate map of its surroundings that is updated in real-time. The same map can be updated with global marine traffic systems like ECDIS in order to increase accuracy even more.

The reason autonomous vehicle implementation takes so much time is that in order to be used it has to be reliable and primarily safe. In order to be safe and reliable, the vehicle needs to be perfected to a point where it is as safe and as reliable as a normal crew operated vessel. Autonomous vessels pose a wide range of different obstacles that need to be solved in order to achieve full autonomy like severe weather, narrow canals, malfunctions on the open sea that need to be repaired, and obstacle avoidance which is not easy for a large ship.

It is very likely that the first step in autonomous shipping will be shore control centers where operators will control a wide range of ships since there is no need for an operator to control the vessel all the time since the ship will be able to sail autonomously and it will notify the operator in case it needs an intervention.[39]

[39] https://www.kongsberg.com/maritime/about-us/news-and-media/our-stories/intelligent-awareness/ (27.07.2020)

- **Autonomous navigation system (ANS)**

As discussed before, in order for autonomous ships to be able to make accurate maneuvers and to avoid obstacles and plan routes they need to have precise situational awareness. In order to have that they need to take advantage of dynamic positioning (DP) systems that are linked with automatic navigation systems (ANS) and that use situational awareness (SA), route planning (RP), and collision avoidance (CA) systems in order to achieve accurate representations of the world surrounding them.[40]

The most important module in the ANS system is the "Virtual Captain" module. Its job is to gather data from all the on-board sensors and systems and examine that data and make decisions in order to complete its journey. Depending on the type of the ship and cargo on-board the Virtual Captain will have different clearance levels, ranging from being fully operator controlled to being fully autonomous.

Dynamic positioning technology allows the ship to maintain its position using its propellers, thrusters, and rudders. It utilizes GPS coordinates and wind information to maintain its precise location even when in rough waters and during bad weather conditions.

The route planning module allows the ship to do various calculations in order to find the most effective way to reach its destination, it is able to place waypoint to split the journey into various points. In case there is an issue it can plan new waypoints, return to the last waypoint the ship passed, and is able to adapt routes to avoid other vessels or obstacles.

The Collision Avoidance module is in charge of ensuring that the vehicle is safe at all times. It works with the route planning module to predict vessel movement in order to plan safe routes and to avoid collision with different kinds of obstacles like the shore, rock formations, shallow sea, and different watercraft.

[40] https://link.springer.com/article/10.1007/s13437-019-00172-0 (27.07.2020)

The situational awareness module is responsible to "feed" the onboard software with all the information regarding the ship's surroundings, both near and far. It extracts information from different sensors on the ship and uses Radar and Lidar modules for longer ranges.

- **Environmental mapping and obstacle detection for autonomous ship navigation**

The term Mapping is used to describe the process of creating a representation of the world. Autonomous ships will have onboard computers responsible for creating different map layers concerning the ship's voyage plan. There will be layers for watercraft, obstacles, water depth, weather conditions which will all be combined into a final map which the vessel will use to plan its voyage and adapt to it as the map changes.[41]

When the connection allows it (mostly near harbors) it will be able to utilize nautical and terrain charts to get updated information concerning it. Every ship in the sea is required to display its location using onboard GPS. The autonomous vessel will be able to use that information to predict locations of other vessels without having the need to look for them with situational awareness software.

- **Sensing the ship's environment**

Different technology will be used for monitoring different surroundings. For example in shorter-range radar and Lidar system are able to provide precise locations of watercraft and is able to provide the dimensions of the located vessel and is able to keep the on-board computer informed about its path and changes in course. Cameras surrounding the ship are able to help with detection and allow the ship operator to actually see the ship's surroundings if there is a need for intervention. Various Near-IR cameras and Thermal LWIR cameras surrounding the ship will be used for night vision and will be able to detect obstacles in various weather conditions. It is important to pin out that Autonomous vessels will be great at finding lost crew in case there is an accident on its path thanks to its thermal cameras which are able to detect humans at a long range in pitch black scenarios.

[41] https://onlinelibrary.wiley.com/doi/full/10.1002/rob.21935 (27.07.2020)

- **Sensor technologies for situational awareness**

The best choice for situational awareness is currently cameras, because of their small size, they are inexpensive and sturdy. Cameras will be able to provide a high definition picture to the operator and will be able to detect obstacles at different ranges. As previously mentioned true night vision cameras and thermal cameras will be able to detect different obstacles and vessels in pitch black conditions.[42]

However, cameras have their disadvantage, they generate massive amounts of memory because of the high definition footage. Since for higher-level autonomy vessels, are not going to have crew quarters there will be plenty of room for servers that will be able to store the generated data. Because of the sheer size of the vessels, they will not be bound with the same restrictions as autonomous cars, there will be plenty of room for data storage.

Cameras are perfect for short-range object detection, however longer ranges will be covered by advanced Radars and Lidars which will be fast, accurate and reliable. There are multiple major Radar and Lidar manufacturers on the market which are competing for business by trying to make their products as best as possible for a good price.

The only disadvantage of lidars and radars is that they have mechanical parts (constantly spinning) which can break because of the constant friction and they will have to be inspected from time to time. Ships will probably be equipped with backup radars in case of a radar malfunction so the vessel can resume its voyage normally.

The perfect examle of all the mentioned autonomous technologies is the vessel Yara birkeland. She will be the worlds first fully electric and autonomous container ship and have zero emissions.

It is designed to fit the role of a feeder ship and will sail between the ports of Herøya, Brevik and Larvik on the Norwegian coast. The ship will have the cargo capacity of 120 TEU and will be equiped with different state of the art technologies allowing autonomous sailing, some of which being; a radar, lidar, automatic indentification system, and IR cameras.

[42] https://arxiv.org/ftp/arxiv/papers/1702/1702.00754.pdf (27.07.2020)

The loading and discharging will be done automatically using autonomous electric cranes and equipment. The ship wont be equipped with ballast tanks, but will use the battery pack as permament ballast.

To ensure safety, three centres with different operational profile are planned to handle all aspects of operation. These centres will handle emergency and exception handling, condition monitoring, operational monitoring, decision support, surveillance of the autonomous ship and its surroundings and all other aspects of safety. An interface towards Yara logistical operation will be implemented at the operational centre at Herøya.

Because of the Covid-19 pandemic the ship was not able to start its journey and become the worlds first autonomous ship. When the situation regarding the epidemic becomes better the ship will be able to do its mayden voyage and setting the bar high for future ships and achieving a milestone for autonomous ships and vehicles in general.[43]

3.3. LEGAL IMPLICATIONS OF REMOTE AND AUTONOMOUS SHIPPING

Maritime law is considered as a functional term used for describing an entire range of laws and other legal sources that govern the legal framework associated with ships and their operation. It includes a range of various legal systems, starting from international law to regional and national rules and right down to local rules. It covers problems with public concerns, like safety, security, and environmental protection also as civil law matters, like contracts of carriage, liability, and compensation for damage, salvage, and rules associated with marine risks and insurance, to name a few.

The idea of a fully autonomous and unmanned ship addresses a really fundamental feature in shipping – the role of the master and the crew on board. Because of this a large portion of maritime laws are ignored, so in order to welcome autonomous shipping new laws concerning them have to be established.

[43] https://www.kongsberg.com/maritime/support/themes/autonomous-ship-project-key-facts-about-yara-birkeland/ (27.07.2020.)

The focus of this master's thesis is on international laws. There are three main types of laws concerning ships. First, there are jurisdictional laws that define state laws and ship obligations. These laws were established in the 1982 UN convention on the Law of the ocean (UNCLOS). Second, are the technical laws covering the environmental regulations and the training of the crew, etc. These laws are usually adopted by specialized UN agencies like the most famous International Maritime Organization (IMO). The third is a series of international laws that define the liability of cargo-related losses and how the claims are made.[44]

A first and fundamental question to be resolved is whether or not ships without a crew onboard are ‘ships’ or ‘vessels’ within the meaning of the convention at all. Both terms are used interchangeably in UNCLOS, but neither is defined. It does, however, follow from the nature of the activities administered by the massive, self-propelled, cargo-carrying, commercially-operated unmanned ships of interest here that they probably will need to be regarded as vessels/ships by virtue of their size, features, and functions. Existing international conventions that define the term ship do not include references to crewing and at the national level, too, the definition of a ship is typically disconnected from the question of whether or not the ship is manned. It might also seem unjustified that two ships, one manned and the other unmanned, doing similar tasks involving similar dangers would not be subject to identical rules that are designed to deal with those dangers.

From the assumption that unmanned ships are ‘ships’ and ’vessels’ within the meaning of UNCLOS follows that they're subject to identical rules of the law of the sea as any ordinarily crewed ship. Identical obligations apply to unmanned ships and their flag states with respect to compliance with international rules. On the opposite hand, they also enjoy identical passage rights as other ships and can't be refused access to other states’ waters merely because they're not crewed.

3.3.1. Liability rules

The challenge with autonomous vehicles is to determine whom to blame in case an accident happens. If the operator turned the autonomous mode on the vessel and the vessel has collided

[44]https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf (27.07.2020)

with some other water-craft who is to blame? The manufacturers of autonomous systems always protect themselves from liability by saying that the system should be at all times be monitored by an operator so if the accident does happen the operator should be to blame. However autonomous ships are built in order to offer safe and reliable sailing in order to compete with normal ships so the accident (if any) will not be major.

The liability question is something that absolutely has to be clearly defined so that every party is familiar with the laws regarding autonomous vessels. As more and more autonomous vessels start sailing the sea so will the laws and regulations adapt to the new standards and proceed on monitoring the performances of these vessels and change the laws accordingly.

4. AUTONOMOUS AIR VEHICLES

When talking about the different autonomous vehicles, the aerial autonomous vehicles have the fastest development plan of all vehicles. Their potential was recognized as early as 1916. From that point researches are continuously working on finding benefits of autonomous air vehicles. Because of the nature of its movement (flying), it is not bound to the same rules as autonomous cars and ships are. Autonomous air vehicles or Unmanned Aircraft Systems (UAS) do not have movement restrictions the same way that ground or sea vehicles do, their flight paths do not have any obstacles and they are free to move wherever they desire. [45]

Depending on whom you ask UAS seem like a futuristic dream but UAS are already used for different jobs to make human life easier all over the world. From firefighting, agriculture, to research, the UAS can do everything, and yet their peak potential is yet to be reached.

Many terms for autonomous air vehicles exist already, the most used ones are: UAS (Unmanned Aircraft Systems), UAV (Unmanned Aerial Vehicle) and maybe the most famous one for us is the term “drone”. The term drone is most commonly used for civil UAS however because of its sour connection with the military drones some people prefer to not call civil UAS, drones.

Currently, there are already fully autonomous UAS that are handling simple tasks like package delivery (Amazon) but as the complexity of the mission increases a human operator is required in order to oversee and intervene when necessary. Almost every UAS is equipped with basic autonomy technology which allows the UAS to safely return home, hold its position in the air, reach waypoints, adapt its speed to maintain longer flight time and basic and advanced anti-collision systems.

[45] https://www.ansys.com/blog/self-flying-planes-vs-autonomous-aircraft (28.07.2020)

4.1. AUTONOMOUS AIR VEHICLES THROUGH HISTORY

Unmanned Aerial Vehicles are the pioneers of autonomous technology with their existence dating back to the year 1849. when they were used by Austrians to attack the Italian city of Venice using unmanned balloons that were loaded with explosives.

Although by today's standard's balloons wouldn't be considered a UAV, at that time they were a breakthrough in unmanned technology. They didn’t show to be the most effective weapon by being very inaccurate and most of the bombs flew in different directions depending on the wind, however they showed the potential of unmanned aerial vehicles and other countries started researching them.

The first successful operation regarding UAS was in 1915 when the British military used aerial photography to their advantage during the Battle of Neuve Chapelle. The Operation was a huge success and the British were able to capture over 1,500 photos of German trench fortifications and they made maps with that information.[46] Because of this operation, the world saw the potential of UAS and they knew where they should focus their research

In 1916 The United States began developing UAV technology during the First World War and they managed to create the first drone, the Kettering Bug. It was a basic aerial torpedo able to strike targets up to 120 km from its launch point. Despite its successful testing, the drone was never deployed because of the rapid development of newer drones it became obsolete very fast. In 1937 during WWII, Reginald Denny created the first remote-controlled aircraft called the Radioplane OQ-2. It was used as a target drone and it was used in the pilot exercise. It was the first mass-produced drone in the U.S. military.[47]

During the early days of drone development, they were considered as too expensive and not reliable, however that changed in the 1980s when drones shifted the advantage to the Israeli

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[46] https://www.feelfreespot.com/unmanned-aerial-vehicles-drone-know-your-drones/ (28.07.2020)
[47] https://historycollection.com/the-story-of-the-kettering-bug-the-worlds-first-aerial-drone/ (28.07.2020)

Air force and won the battle over the Syrian Air Force. The drones were used to destroy dozens of Syrian aircraft with minimal losses.

The U.S. saw the potential of the Israeli drones and started the Pioneer UAV program in the 1980s in order to fulfill the need for cheap and reliable drones. In 1986 a brand new drone was created as the result of the joint operation between the U.S. and Israel, the drone was called RQ2 Pioneer and was a medium-size reconnaissance aircraft.[48]

The U.S. saw the military potential of drones and began actively researching them, by 1990 miniature and micro UAVs were introduced and in 2000 the U.S. deployed its most famous drone the "Predator" while on the hunt for Osama Bin Laden. The drones were constantly used and became a recognizable symbol of the U.S. Air Force until 2018 when it was replaced by a newer and more capable version of the predator, the MQ-9 Reaper or often called as the "Predator B"[49]

Picture 9. MQ-1 Predator control room used by the U.S in 2007.

[48] RQ-2 Pioneer: The Flawed System that Redefined US Unmanned Aviation, Richard Major, Major, USAF. Maxwell Air Force Base, Alabama February 2012
[49] https://www.airforce-technology.com/projects/predator-uav/ (28.07.2020)

Source: https://theaviationist.com/2012/10/15/six-mq-9-reaper-four-mq-1-predator-drones-flying-simultaneously-set-new-world-record/ (28.07.2020)

In 2014 Amazon recognized the commercial potential of the UAS and decided to develop drones that autonomous deliver packages to the buyer's front yard. The first drone-delivered package was achieved in 2016 with remarkable results, however, the operation has hit an obstacle which they still didn't overcome, the law. Today, the legislation concerning all aspects of commercial UAS is not yet fully prepared but they did get a green light recently regarding their operations as long as the drones are within the "line of sight". This does not mean you should expect autonomous drone delivery tomorrow but it is a huge step in the right direction.[50]

Today, unmanned aircraft systems, or so-called "drones" are rapidly becoming a part of our everyday lives. They are quickly increasing in numbers and complexity. The way we use drones ranges from recreation to commercial and military applications. Currently, only in the United States, there are over 1,673,404 registered drones of which 481,848 are in commercial use and 1,188,045 in recreational use. Also, there are 187,355 certified drone pilots. These numbers are growing by the day and are proof that commercial and recreational drone technology is here to stay.

[50]https://paxex.aero/2020/08/amazon-prime-air-drones-secure-faa-exemption/ (30.08.2020)

4.2. AUTONOMOUS AIR VEHICLE CLASSIFICATION

When classifying UAS there is no standard, the military uses their own classification and civilians have their own classification. UAS are either classified by size, range, or endurance. When classifying according to size the most commonly used classification is:[51]

- Very small UAVs
  - Micro or Nano UAVs
- Small UAVs
  - Mini UAVs
- Medium UAVs
- Large UAVs

UAVs also can be classified according to the ranges they can travel and their endurance in the air using the following sub-classes developed by the US military:

- Very low-cost close-range UAVs
- Close-range UAVs
- Short-range UAVs
- Mid-range UAVs
- Endurance UAVs

[51] https://www.e-education.psu.edu/geog892/node/5 (28.07.2020.)

According to the U.S. Department of Defense, UAVs are classified into five categories:

Table 2: UAV classification according to the U.S. Department of defense

Category	Size	Maximum Gross Takeoff Weight (MGTW)(lbs)	Normal Operating Altitude (ft)	Airspeed (knots)
Group 1	Small	0-20	<1,200 AGL	<100
Group 2	Medium	21-55	<3,500	<250
Group 3	Large	<1320	<18,000 MSL	<250
Group 4	Larger	>1320	<18,000 MSL	Any airspeed
Group 5	Largest	>1320	>18,000	Any airspeed

Source: made by the student in reference of: https://www.e-education.psu.edu/geog892/node/5 (28.07.2020.)

This master's thesis is focusing on the most commonly used classification and that is the classification according to size:

- Very small UAVs

The very small UAV class applies to UAVs with dimensions starting from the scale of a large insect to 30-50 cm long. These very small UAS are inspired by insects and because of that, they have small rotary or flapping wings. Because of their extremely small size, they can be used for reconnaissance. This is the most popular category since most of the UAS belong in this category because of their cheap price and reliability. Most commercially sold drones are in this category ranging from different sizes up to 50 cm long. They are most commonly used by people as a hobby or for aerial photography and videography.

- Small UAVs

Small UAVs or mini-UAVs are all UAVs that have a dimension greater than 50 cm and are not larger than 2 meters. Most UAVs in this category are launched by hand and are designed with fixed wings.

- Medium UAVs

The medium UAV category applies to UAVs that are too heavy to be carried by one person but are still smaller than a small aircraft. They usually have a wingspan of about 5-10 meters and can carry payloads of 100-200 kg.

- Large UAVs

The large UAV class applies to the large UAVs used mainly for combat operations by the military. Examples of these large UAVs are the US Northrop Grumman Global Hawkreconnaissance and science drone.

Picture 9: US Northrop Grumman Global Hawkreconnaissance and science drone.

Source: https://www.nasa.gov/multimedia/imagegallery/image_feature_2362.html(28.07.2020.)

4.3. LEVELS OF AUTONOMY

Because of their long history of military benefits UAVs have been a research focus for many countries. This has led to rapid and major improvements to their autonomy and to the technology allowing the UAVs to function. Since weight is of major importance for aircraft UAVs have been separated in different roles so that all the equipment they carry is essential for their role.

For a UAV to function properly it has to be equipped with necessary technologies allowing it to fly long periods of time, it needs to be able to detect obstacles and avoid them and to monitors its remaining fuel or power in order to allow a safe return to the landing spot. Comprehensive analyses have been carried out in order to analyze all technologies creating an autonomous UAV and to point out the most important ones and focus on improving them.[52]

To determine the levels of autonomy of a UAV the following questions have to be considered:

- Why is autonomy addressed in UAVs?
- How much autonomy is required for a UAV?
- How to assess the autonomy level of UAV?

4.3.1. Why is autonomy addressed in UAVs

The UAVs have been created in the purpose of conducting dangerous missions so that human life is not put in danger. It is now possible to gather reconnaissance in hostile areas without the need to jeopardize human life.

The first few generations of UAVs were very limited in terms of movements and autonomy however their potential was quickly recognized.

The UAV is able to fly autonomously but a link between an operator and the UAV is crucial in order to adapt to new parameters and the operator must be able to take over in difficult parts of

[52] US Department of Defense, “Unmanned Aircraft Systems (UAS) Roadmap 2005 – 2030”, 2005.

the mission. That necessary link between the operator and the UAV is the weakest link UAV operation chain.

In order for the operator to have a direct link with the UAV a connection has to be established, that is not hard, what is hard is to keep that connection at a fast enough level in order to decrease latency. With reaction time being an important factor in some missions it is of foremost importance that the connection between the operator and the UAV is as best as possible at all times. However, due to different ways of intentional or unintentional signal jamming, it is simply not possible to rely at all times on an operator.

Moreover, the analysis of the records relative to the mishap of in-service UAV has shown that a significant number of events are due to operator errors.[53]

In order to overcome these shortfalls, a solution is to create a fully autonomous UAV. That the operator can still oversee and make changes if necessary but the UAV will have its own decision-making systems that will not relly on the operator.

This level of full autonomy will allow operators on overseeing multiple UAVs at the same time and only focus on important events in the mission.

With this technology when a loss of connection occurs, the operator will be able to predict the course of action of the UAV and the UAV will know to wait for the connection to be established if a major operation part has to happen which requires the operator link.

In order to achieve complete autonomy the UAV needs to be equipped with the following technology:

- Advanced sensors, which will allow the air vehicle to avoid obstacles and detect different air vehicles and anti-aircraft missiles in the military.
- Self-awareness, which will allow the vehicle to create routes that limit its exposure to hostile territory or in commercial use to avoid prohibited regions such as airports or government buildings.

[53] Office of the Secretary of Defense, "Unmanned Aerial Vehicle Reliability Study", 2003

- Self-diagnosis, which will allow the aircraft to detect errors in the system or potential mechanical failures and to adapt to new events. For example, if the drone is a quadcopter and one propeller fails the aircraft will be able to detect that and adapt the thrust in other propellers in order to still maintain a stable flight to the landing spot.
- Overall mission management, which will allow the UAS to re-plan the mission and adapt it to real-time events. In case of a rescue drone searching for missing people in the night the drone knows it should switch to night-vision or thermal cameras. Another example is if the wind starts picking up the UAS will know it will use more power than planned and adapt its battery management accordingly.

4.3.2. How much autonomy is required for a UAS

The UAS have different autonomy levels depending on their purpose. Simple agriculture drones that are equipped with fertilizers only have to takeoff, fly in a certain pattern to fertilize the field and land. This requires only basic autonomy levels, but for example search and rescue drones need to be able to know what to look for, be equipped with different cameras ranging from normal high definition cameras to high power night-vision and thermal cameras. They need to be equipped with 360-degree sensors so the drone can avoid trees or power lines since the drone will be flying at lower altitudes.

It is important that UAS can be operator controlled but only if the operators want to do it manually and that the UAS does not require it. The only mandatory operator action is the input of parameters for example selecting the area of the field that has to be fertilized so that the drone knows what area to cover.

4.3.3. How to assess the autonomy of a UAV

The autonomy level of the UAV can be assessed by the mission it is executing. Simpler tasks required less autonomy and more complicated tasks require higher self-awareness and higher autonomy levels. The NATO WG defines for levels to classify the autonomy of a UAV system:[54]

Level 1: Remotely Controlled System - System reactions and behavior depend on operator input

Level 2: Automated System - Reactions and behavior depend on fixed built-in functionality (preprogrammed)

Level 3: Autonomous non-learning system - Behaviour depends upon fixed built-in functionality or upon a fixed set of rules that dictate system behavior (goal-directed reaction and behavior).

Level 4: Autonomous learning system with the ability to modify rules defining behaviors - Behaviour depends upon a set of rules that can be modified for continuously improving goal-directed reactions and behaviors within an overarching set of inviolate rules/behaviors.

4.4. AUTONOMOUS AIR VEHICLE APPLICATIONS

Since the early days of autonomous air vehicles researched were looking for ways to implement UAS in order to maximize their efficiency. Society moved far past the point where UAS is only used for military purposes. Today most jobs can benefit from UAS usage, from real estate agents using drones to get aerial pictures of houses to electricians using drones to identify errors on building roofs or high power towers.

4.4.1. Agriculture

Agriculture is shaping to be the most promising area of commercial UAV applications. THE Association for Unmanned Vehicle Systems International (AUVSI) has estimated that agriculture will be the primary civil use of UAVs and that 90% of the market of UAVs will consist of a mixture of public safety applications and Agriculture UAVs.

[54] NIAG (SG/75) “Pre-feasibility Study on UAV Autonomous Operations”, 2004.

UAVs are already being used all over the world for agriculture applications. The most dominant Countries which have recognized the potential of UAVs for agriculture are Brazil and Japan. UAVs are a great solution for agriculture because they can help farmers fertilize big fields without using planes which are often used to cover big areas. UAVs can also be used for livestock monitoring, or to check fields for any crop diseases. Industrial farms can have fields up to 8 km^2 which is a huge distance for a human to cover, but with the use of a UAV the farmer has the whole field at his fingertips. As the research and development of UAVs continues it is possible that the drones will also be able to plant and even harvest crops or be used in pollination process. Planes and helicopters are already used for fertilizing or pollinating huge fields and because of the cost-efficiency of the drones more and more farmers and switching to them. Also by using planes you need to fly low enough so that the pesticide or fertilizer does not disperse too much in the air and there are accidents where the farmers crashed the plane. This risk is eliminated by using drones. The farmer can be at home on his sofa and work on the field at the same time, which is a major breakthrough.

Picture 10: DJI MG-1 agricultural spraying drone

Source: http://flight-evolved.com/dji-agras-mg1/ (02.08.2020)

4.4.2. Public services

UAVs are making our lives safer, and not by a small margin. Drones are becoming absolute heroes of every search and rescue operation because of their ability to fly in strong wind situations and in bad weather. Because of their equipment, they are able to spot people at long distances and in pitch black conditions because of their FLIR cameras which detect body heat. The most effective use of drones is for search and rescue situations because of their fast speed and low profile they can reach longer distances fast and move low in the terrain avoiding trees or other obstacles with ease. If for example a person climbing the mountain has an accident the search and rescue center has to send people looking for him and for the rescuers to reach the person it usually takes multiple hours. With the use of a drone, the person can be located much faster and the drone can be fitted with first aid gear which the hurt person can apply to himself with the help of a rescuer talking to him via the drone.

Croatia is one of the first countries in the EU to use AUVs for maritime surveillance. The drone is currently being tested and it is used to patrol the Adriatic coast and look out for sailors and other people engaging in sea-related activities. If the search and rescue teams get a call for help, the drone is first to act.[55]

[55]https://mmpi.gov.hr/vijesti-8/drzavni-tajnik-josip-bilaver-na-predstavljanju-bespilotnog-zrakoplovnog-sustava-za-nadzor-jadrana/20811 (02.08.2020)

Picture 11: DJI Matrice 300 RTK multipurpose public service drone

Source: https://www.youtube.com/watch?v=V-4Om_4n998 (02.08.2020.)

4.4.3. Aerial surveillance

As previously mentioned the UAS ability of aerial surveillance cannot be beaten. Because of their fast speed and ability to be equipped with different cameras gives them the ability to be used in wide ranges of applications. Recently environmentalists have started utilizing drones for aerial surveillance and spotting whaling vessels. Drones are also used in factories for safety inspections and in oil rigs for gas pipe inspections. Because of their availability, different countries even proposed banning them, which later came down to regulate their use. That is why today more and more areas are marked as "no-fly zones", especially government properties and military installations.[56]

[56] https://www.airbornedrones.co/surveillance-and-security/ (02.08.2020)

4.4.4. Media

The potential of using drones for aerial photography was quickly recognized since the drone already has to be equipped with cameras to allow the pilot to fly it. When the potential was recognized it all came down to putting the biggest camera the drone can carry and start filming. That is true even today. Large and expensive drones are fitted with expensive Hollywood grade cameras are used for almost every movie or music video. Because of its mobility and ease of use, it became an essential tool for every videographer. UAVs are becoming more and more widely used by paparazzi to allow them to film over the walls of celebrity properties and allow them the record the celebrities without them noticing from longer distances. This is a serious cause for concern and is an important factor in preserving human privacy and is a major factor in the laws concerning drones. [57]

4.4.5. Delivery

The fast speed and ease of control gave people the ability to use drones for a wide range of applications, one of which was delivery. Today more expensive drones are autonomous to the point where you can just select the end destination and the drone can fly autonomously, reach the destination and return safely to the starting location. This autonomy gave companies like Amazon an idea to utilize it for delivery purposes. As mentioned in this thesis before, in 2014 Amazon recognized the commercial potential of the UAS and decided to develop drones that autonomous deliver packages to the buyer's front yard. The first drone-delivered package was achieved in 2016 with remarkable results, however, the operation has hit an obstacle which they still didn’t overcome, the law. The legislation concerning all aspects of commercial UAS is not yet fully prepared however they did get a green light recently regarding their operations as long as the drones are within the “line of sight”. This does not mean you should expect autonomous drone delivery tomorrow but it is a huge step in the right direction.

[57] https://www.businessinsider.com/heres-how-drones-are-transforming-news-media-2017-1 (02.08.2020)

Just a few days ago Amazon got a green light from the Federal Aviation Administration which was previously not allowing the drones to perform autonomous deliveries. This new legislation concerning drones is a step in the right direction allowing companies to use drones for deliveries.[58]

Picture 12: Amazon delivery drone

Source: https://www.businessinsider.com/drone-delivery-services(05.09.2020)

4.5. LEGALITY AND REGULATIONS CONCERNING AUTONOMOUS AIR VEHICLES

Since the spread of UAVs is a relatively recent event, laws are not entirely clear on their use. The foundations have been laid in terms of legislation concerning them. For example, you cannot fly the drone near any airports and government buildings. In some countries, you have to inform the authorities in advance of the space where you will fly the drone so that they can confirm that no airplanes will pass in that airspace so that no one is put in jeopardy. Also, there is a limit

58 https://futurism.com/the-byte/amazon-permission-start-drone-deliveries (05.09.2020)

on how high you can fly in order to avoid collision with other aircraft and thus putting human life in danger. It is also forbidden to record other private properties from a close distance and if caught you the person operating the drone can be prosecuted. The laws regulating the use of UAVs are fresh and the government is monitoring the use of the drones, so that when the need to adapt the laws comes, the legislation will be ready. The fundamental laws regarding drone use in Croatia are similar to the rest of the world, for example:[59]

- Do not fly your drone higher than 120 meters above the surface or 50 meters above the obstacle, whichever is greater.
- Maintain a visual line of sight with the drone at all times.
- Drones must maintain a distance of at least 30 m away from uninvolved people unless the low-speed mode is activated and the maximum speed does not exceed 3m/s. In that case, the drone must remain at least 5 m away from uninvolved people.
- The minimum allowed distance from a UAV in flight to a group of people is 50 m.

4.6. SAFETY AND SECURITY

As with any autonomous vehicle, there are risks that come with it. But in theory, the room for error is very small and if used according to the guidelines there shouldn't be any. Unmanned aerial vehicles are getting "clever" by the day and even if a collision does happen if will be rare and should be harmless because the vehicle will slow down or in case of loss of connection or battery the vehicle will land autonomously.

4.6.1. Collision

As with any vehicle, the primary risk for concern is the risk of collision, in this case with other aircraft, people, property, or vehicles in general. UAVs carry less risk than the traditional aircraft since they do not carry any passengers so that risk is eliminated, however as the technology is advancing, bigger and faster UAVs are put on the market and a drone of 10 kg can cause serious damage in case of collision. To mitigate the risk the UAVs are equipped to prevent collision and

[59] https://uavcoach.com/drone-laws-in-croatia/ (05.09.2020)

the operator cannon override these settings. The drone has 360-degree sensors that allow the drone to autonomously avoid obstacles and the drone constantly does battery calculations so that it knows when to return to the start position so that it does not power mid-flight, even if the battery does reach 0% the drone still power left to slowly descend to avoid and damage. Laws forbid the drone to fly close to other people so if executed properly drone flight should be collision-free.

4.6.2. Loss of data link to controller

Commercial drones can fly autonomously but still have an operator who is responsible for the drone. If the loss of connection between the operator and the drone happens, the drone maintains its position safely and can return to the previous point where the connection was established. The drone knows where to return because it has an onboard GPS and knows from which point it started flying.

4.6.3. Cyber risk

When talking about autonomous technology or even technology in general there is always the risk of someone hacking the device and causing problems. Drones however seem to be perfectly safe so far because nobody can come in physical contact with the drone while it is flying, and when it is close to the ground or landing the operator can see the drone. The biggest cyber risk for drones is their use for illegal video recording or photography, whether it is government buildings or other citizen's houses. The person piloting the drone has to always be aware of the drones surrounding in order to avoid forbidden areas.[60]

[60] https://www.insuretrust.com/hacking-drones-the-cybersecurity-risks-you-need-to-know/ (02.08.2020)

5. FUTURE OF AUTONOMOUS VEHICLES AND THE IMPACT OF COVID-19 ON AUTONOMOUS TECHNOLOGY

It is estimated that in the matter of a few years one in five vehicles will have some sort of wireless network connectivity. This network connectivity is not simple as the number of autonomous vehicles on the road increases so will the road infrastructure have to adapt as well. Completely autonomous vehicles require an estimate of 4,000 GB of data each day for all the onboard technology. Further, a recent study estimated that an electric-powered haulage truck would guzzle up the energy needed to power 4,000 homes in order to completely rechange itself. It can only be estimated how much power would a fully electric ship requires in order to set sail.[61]

In order to support the mass data transfer for vehicle-vehicle and vehicle-road data transfer, both the road infrastructure and the cars themselves have to be equipped with lightning speed 5G internet speeds in order to keep up with the ever-increasing demand for high-speed internet.

The complete autonomous vehicle will not arrive overnight and the world has the opportunity to prepare for their certain arrival. They will change the way we look at our everyday lives and the way we do things for the better.

Because of the huge impact that the COVID-19 has on the whole world autonomous technology has started to stand out more and more because of the high infectivity rate between humans. China was the first to implement the use of autonomous "robots" in the hospital to deliver food to infected patients in order to reduce the necessary exposure. Now as the risk for infections raises more and more people in China and all over the world to rely on autonomous taxis in their daily routine to reduce exposure to other humans.

According to Zhenyu Li from Baidu Intelligent Driving Group "Having been through the pandemic and supported the front line, we realize automation and intelligence are the best solutions for humans to respond to large-scale emergencies".

[61] https://channels.theinnovationenterprise.com/articles/preparing-for-an-autonomous-future (02.08.2020.)

Baidu as one of the leaders in autonomous vehicle technology has released 104 self-driving cars in 17 cities that are helping to carry out frontline anti-epidemic work such as disinfecting, cleaning, and transport logistics with the support of partner companies.

The vehicles are delivering food and supplies to the Beijing Haidian Hospital that feed over 100 frontline staff members who are treating a growing patient base. Additionally, self-driving vehicles are deployed daily that disinfect roads. These self-driving vehicles can carry out full disinfection operations covering wide areas. Additionally, these vehicles are also patrolling the streets to warn people of breaking the lockdown rules.

Because human contact in the outside world is becoming more and more dangerous people started opting for autonomous vehicles to get from point A to point B and choose normal taxis less. Autonomous technology is here to help us avoid unnecessary human contact and protect our lives.

6. CONCLUSION

Recent optimistic news concerning autonomous vehicles make it easy for people to think that autonomous vehicles are closer than ever, which is true. However, there are still a lot of obstacles to overcome to a future where autonomous vehicles are a common thing.

Autonomous cars, ships, and aircraft are closer than ever to the point of their integration in our lives. Tesla, Baidu, Waymo, and Uber are the leaders in the autonomous car industry and they have reached a point when their vehicles are already in use and they are expecting exponential growth in sales over the upcoming years. Most of the new luxury vehicles are leaning to the 4. and 5. level of autonomy with some vehicles already achieving the final autonomy level where the vehicle is able to do everything itself. As time passes more and more vehicles on the road will be of higher autonomy levels and in a few years, autonomous cars will change the driving habits that people are accustomed to.

Autonomous ships are the slowest of the three categories to adapt to autonomous technology because of their sheer size, infrastructure complexity, and legislation obstacles. However there a pioneering vessel “Yara Birkeland” that was supposed to have a maiden voyage this year, but because of the Covid-19 pandemic didn’t have the chance. She is ready to set the bar high for other ships and is waiting for a green light to start sailing. Since the focus on the environment is increasing major ports decided to switch to electric cranes and other electric equipment which makes it easier to implement autonomy. As the number of autonomous ships increases ports will have to upgrade their infrastructure to suit the new ship types, this change will start with the biggest ports that focus on eco-friendly operation.

Autonomous aircraft have reached the point where the UAV has the ability to reach pre-determined waypoints placed by the operator. Their autonomous technology is at a peak but still manages to evolve with more and more advanced features. Autonomous air vehicles are already used in a wide range of commercial uses like in agriculture and search and rescue operations. Big companies like Amazon have recognized their potential and started implementing drones for package delivery. All possible uses for UAS are yet to be discovered and people should become accustomed to their presence because they will become a major part of our lives.

Legislation has proven to be a big obstacle for autonomous vehicles since it is new subject laws are yet to be fully adapted to define their use. In the case of autonomous cars, the laws are not clear about who is reliable in case of an accident. In the case of laws concerning autonomous ships, they reached an obstacle because the law strictly says that a ship is a vessel with a captain and crew on board. Since autonomous ships insist on not having a captain (at least not on board) and a crew, according to the law they are not ships and therefore cannot enter territorial waters. The law is expected to change as the number of autonomous vehicles increases. It is hard to write the law for something new, and with time the law will adapt to the event and that is gonna lead to a defined set of laws concerning each autonomous vehicle and defining its use.

Autonomous technology is already a part of our lives, from the basic functions that help us drive our cars and stay safe to refrigerators switching to “vacation mode” which saves power when people leave for a vacation. The impact of autonomous technology is increasing by the day as their new applications are discovered. Each autonomous vehicle is more environmentally friendly than their fuel consuming counterpart which means that autonomous technology is not only making our lives safer and easier but is also helping to protect our environment in the process.

LITERATURE

BOOKS:

1. James M. Anderson, et al. (2014), Autonomous Vehicle Technology A Guide for Policymakers, RAND Corporation
2. Arthur, W.B. The Nature of Technology: What It Is and How It Evolves, New York, 2009
3. Greve, H. R. Bigger and safer: the diffusion of competitive advantage. Strategic Management Journal, 2009
4. F.W. Geels. Technological Transitions and System Innovations. Cheltenham, UN, 2005
5. Håkansson, H., Ford, D., Gadde, L.-G., Snehota, I., & Waluszewski, A. Business in Networks. Chichester, 2009
6. Levinson, M., The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger. Princeton University Press, Princeton, NJ, 2006
7. Yoo, Y. – Boland Jr., R.J. – Lyytinen, K. – Majchrzak, A. Organizing for Innovation in the Digitized World. Organization Science, 2012

ARTICLES:

1. Allison Arieff (2013), “Driving Sideways,” New York Times, 23 July 2013
2. Tom Bamonte (2013), “Autonomous Vehicles: Drivers for Change,” Roads and Bridges, (www.roadsbridges.com), Summer
3. Brad Berman (2011), History of Hybrid Vehicles, Hybrid Cars
4. Burkhard Bilger (2013), “AutoCorrect: Has The Self-Driving Car At Last Arrived,” New Yorker, 25 November 2013
5. Daniel J. Fagnant and Kara M. Kockelman (2013), Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations, Eno Foundation
6. Fehr & Peers (2014), Effects of Next-Generation Vehicles on Travel Demand & Highway Capacity, Fehr and Peers
7. Thomas Fray (2013), Driverless Cars: A Driving Force Coming to a Future Near You, Futurist Speak
8. Brian Fung (2015), “Driverless Cars Are Getting Into Accidents, But The Police Reports Are Not Being Made Public,” Washington Post

9. Lee Gomes (2014), “Hidden Obstacles For Google’s Self-Driving Cars: Impressive Progress Hides Major Limitations Of Google’s Quest For Automated Driving,” MIT Technological Review, 28 August 2014

10. Erick Guerra (2015), “Planning for Cars That Drive Themselves: Metropolitan Planning Organizations, Regional Transportation Plans, and Autonomous Vehicles,” Journal of Planning Education and Research

11. David Levinson (2015), “Climbing Mount Next: The Effects of Autonomous Vehicles on Society,” Minnesota Journal of Law Science and Technology

12. AAWA Position Paper © Rolls-Royce plc Registered office: 62 Buckingham Gate, London, 2016

13. Office of the Secretary of Defense, “Unmanned Aerial Vehicle Reliability Study”, 2003

14. Patrick Chisan Hew, “The Generation of Situational Awareness within Autonomous Systems – A Near to Mid Term Study – Issues”, DSTO-GD-0467, 2006

15. National Institute of Standards and Technology, “Autonomy Levels for Unmanned Systems (ALFUS) Framework”, Version 1.1, 2004

16. NIAG (SG/75) “Pre-feasibility Study on UAV Autonomous Operations”, 2004.

17. Michael Freed, Robert Harris, Michael Shafto, “Measuring Autonomous UAV Surveillance Performance”, 2004

18. RQ-2 Pioneer: The Flawed System that Redefined US Unmanned Aviation, Richard Major, Major, USAF. Maxwell Air Force Base, Alabama February 2012

LAWS, REGULATIONS AND ACTS:

1. United Nations convention on the Law of the Sea

INTERNET SOURCES:

1. https://media.daimler.com/marsMediaSite/en/instance/ko/The-PROMETHEUS-project-launched-in-1986-Pioneering-autonomous-driving.xhtml?oid=13744534(03.07.2020.)

2. https://www.wired.com/brandlab/2016/03/a-brief-history-of-autonomous-vehicle-technology/ (3.07.2020.)

3. https://medium.com/@davidrostcheck/the-self-driving-car-from-1994-fb1ec617bd5a (3.07.2020.)

4. http://www.argo.ce.unipr.it/argo/english/flyer_en.pdf (3.07.2020.)

5. https://www.autoevolution.com/news/mercedes-benz-had-autonomous-cars-back-in-1985-before-it-was-cool-93769.html (03.07.2020)
6. https://www.darpa.mil/news-events/2014-03-13 (04.07.2020.)
7. https://www.wired.com/story/guide-self-driving-cars/(04.07.2020.)
8. https://www.synopsys.com/automotive/autonomous-driving-levels.html (08.07.2020.)
9. https://www.safercar.gov/Vehicle+Shoppers/Safety+Technology/ldw/ (08.07.2020)
10. https://www.everythingrf.com/community/automotiveradarbasics#:~:text=Automotive%20radars%20are%20used%20to,'%20distance%2C%20speed%20and%20direction.(10.07.2020.)
11. https://www.mdpi.com/1424-8220/19/19/4108/htm (11.07.2020.)
12. https://www.iihs.org/topics/advanced-driver-assistance (11.07.2020.)
13. https://www.safewise.com/resources/motion-sensor-guide/ (11.07.2020)
14. https://www.brainkart.com/article/Anti-lock-braking-system-(ABS)_5068/ (11.07.2020)
15. https://www.caranddriver.com/features/a27888229/power-steering/ (11.07.2020)
16. https://www.engadget.com/2019-11-03-tesla-autopilot trafficcones.html#:~:text=Tesla%20is%20quietly%20rolling%20out,take%20control%20around%20construction%20work (12.07.2020.)
17. https://www.transportation.gov/(12.07.2020.)
18. https://onlinemasters.ohio.edu/blog/the-future-of-driving/ (12.07.2020.)
19. https://www.marketplace.org/2020/04/06/universal-basic-income-was-a-fringe-idea-then-the-covid-19-pandemic-happened/ (12.07.2020)
20. https://www.nytimes.com/2017/03/23/automobiles/wheels/self-driving-cars-elderly.html (14.07.2020.)
21. https://home.kpmg/xx/en/home.html (14.07.2020.)
22. https://onlinemasters.ohio.edu/blog/the-future-of-driving/ (14.07.2020.)
23. https://home.kpmg/xx/en/home.html (14.07.2020.)
24. https://eu.freep.com/story/money/cars/2020/01/08/car-hacking-technology/2841847001/ (14.07.2020)
25. https://www.mes-insights.com/5-top-autonomous-vehicle-companies-to-watch-in-2020-a-910825/ (17.07.2020.)
26. https://www.cbinsights.com/research/autonomous-shipping-trends/ (23.07.2020.)

27. https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf (23.07.2020.)

28. https://www.feelfreespot.com/unmanned-aerial-vehicles-drone-know-your-drones/ (23.07.2020.)

29. https://historycollection.com/the-story-of-the-kettering-bug-the-worlds-first-aerial-drone/ (23.07.2020.)

30. https://www.e-education.psu.edu/geog892/node/5 (23.07.2020.)

31. https://www.sciencedirect.com/science/article/pii/S2405535214000035 (25.07.2020)

32. https://www.ship-technology.com/features/ports-autonomous-shipping/ (25.07.2020)

33. https://www.kongsberg.com/maritime/about-us/news-and-media/our-stories/intelligent-awareness/ (27.07.2020)

34. https://link.springer.com/article/10.1007/s13437-019-00172-0 (27.07.2020)

35. https://onlinelibrary.wiley.com/doi/full/10.1002/rob.21935 (27.07.2020)

36. https://arxiv.org/ftp/arxiv/papers/1702/1702.00754.pdf (27.07.2020)

37. https://www.ansys.com/blog/self-flying-planes-vs-autonomous-aircraft (28.07.2020)

38. https://www.feelfreespot.com/unmanned-aerial-vehicles-drone-know-your-drones/ (28.07.2020)

39. https://historycollection.com/the-story-of-the-kettering-bug-the-worlds-first-aerial-drone/ (28.07.2020)

40. https://www.airforce-technology.com/projects/predator-uav/ (28.07.2020)

41. https://channels.theinnovationenterprise.com/articles/preparing-for-an-autonomous-future (02.08.2020.)

42. https://www.technologyreview.com/2020/05/18/1001760/how-coronavirus-is-accelerating-autonomous-vehicles/ (02.08.2020.)

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KRATICA	PUNI NAZIV NA STRANOM JEZIKU	TUMAČENJE NA HRVATSKOM JEZIKU
LOA	Levels of autonomy	Često se koriste za opisivanje do koje mjere stroj može samostalno djelovati
DP	Dynamic positioning	Odlazak broda natrag na unaprijed postavljeno sigurno mjesto
ETA	Estimated time of arrival	Procijenjeno vrijeme dolaska
IMO	International Maritime Organization	Međunarodna pomorska organizacija
SA	Situational awareness	Situacijska svijest vozila ili plovila
ECDIS	Electronic Chart Display and Information System	Elektroničke pomorske karte
CA	Crash-avoidance system	Module za izbjegavanje sudara
ANS	Autonomous navigation system	Autonomni navigacijski sustav
RP	Route planner	Modul planiranja rute
VC	Virtual captain	Virtualni kapetan
GNSS	Global navigation satellite system	Globalni navigacijski satelitski sustav
UNCLOS	United Nations Convention on the Law of the Sea	Konvencija Ujedinjenih naroda o pomorskim zakonima
SAE	The Society of Automotive Engineers	Društvo inženjera automobila (SAE)

ADAS	Advanced driver-assistance systems	Napredni sustavi za pomoć vozaču
LDW	Lane departure warning	Upozorenje o odlasku u traku
LKS	Lane-keeping system	Sustav održavanja trake
PIR	Passive infrared sensor	Pasivni infracrveni senzor
ABS	Anti-lock braking system	Sustav protiv blokiranja kotača vozila
TCS	Traction control system	Sustav kontrole proklizavanja
AWD	All-wheel drive	Pogon na sve kotače
ESC	Electronic stability control	Elektronska kontrola stabilnosti
EDL	Electronic differential lock	Elektronska blokada diferencijala
DSR	Dynamic steering response	Dinamičan odziv upravljača
ECU	Engine control unit	Upravljačka jedinica motora
EBD	Electronic brakeforce distribution	Elektronska distribucija kočnih snaga
TCS	Traction control unit	Upravljačka jedinica za vuču
SA	Situational awareness	Situacijska svijest
CA	Collision Avoidance	Izbjegavanje sudara
RP	Route planning	Planiranje rute
VC	Virtual captain	Virtualni kapetan
UAS	Unmanned aerial systems	Bespilotni zračni sustavi

AUVSI	The Association for Unmanned Vehicle Systems International	Međunarodno udruženje za sustave bespilotnih vozila