Gabriel Pereira Perdigao

7th EMship cycle: October 2016 – February 2018

Master Thesis

Concept of operation: Unmanned Maintenance Dredging

Supervisor: Dr. Maciej Taczała, West Pomeranian University of Technology, Szczecin, Poland
Internship tutor: M.Sc Tomasz Msciwujewski, DNV GL Maritime, Gdynia, Poland
Reviewer: Professor Robert Bronsart, University of Rostock, Rostock, Germany

Szczecin, January 2018

- DNV GL is an international accredited registrar and classification society headquartered near Oslo, Norway.
- It holds 21% of the market share, being the world's largest classification society, providing services for 13,175 vessels and mobile offshore units.
- It was created as a result of a merger between Det Norske Veritas (Norway) and Germanischer Lloyd (Germany).
- Internship performed at DNV GL – Gdynia Office from July 3rd to October 27th, 2017.
- Proposal for internship :Research about unmanned vehicles.

Contents:

- 70% of earth's surface is covered by water;
- Nearly 90% of goods are transported by sea;
- Maritime industry agonizes year by year looking for ways to reduce operational costs and increase efficiency;
- Crewless car and aircrafts are a reality.

Retrieved January 29, 2018 from source: autocar.co.uk

Retrieved January 29, 2018 from source: geek.com

- Unmanned vessels:
  - Explicitly by definition, no one is on board;
  - Can be towed by pushing boats;
  - Autonomous architecture is not required;
  - Remote-controlled

- Autonomous vessels:
  - Awareness situation;
  - Artificial Intelligence;
  - Collision avoidance system;
  - Robust algorithm;
  - Smart vessels;
  - Able to take decisions based on the work environment.

- **GOAL: Crewless ship with autonomous system on board**

- Major applications:

  - Mainly for shipping;
  - Short-sea shipping (Territorial waters);
  - Deep-sea shipping (Open sea).

- Local applications:

  - Dredging vessels;
  - Submarines
  - Firefighter crafts;
  - Offshore support vessels;
  - Fishing vessels;
  - Tugboats;
  - Skimmer boats;

- Why autonomous/unmanned dredging?:

  - High production is mandatory due to elevated operational costs with fuel and workforce;

  - Dredging market invests considerable amount of money to develop state-of-the-art technology in order to remove material from seabed using as less as possible resources;

  - Operational costs for small to medium harbor basins can be a burden to their expenses.

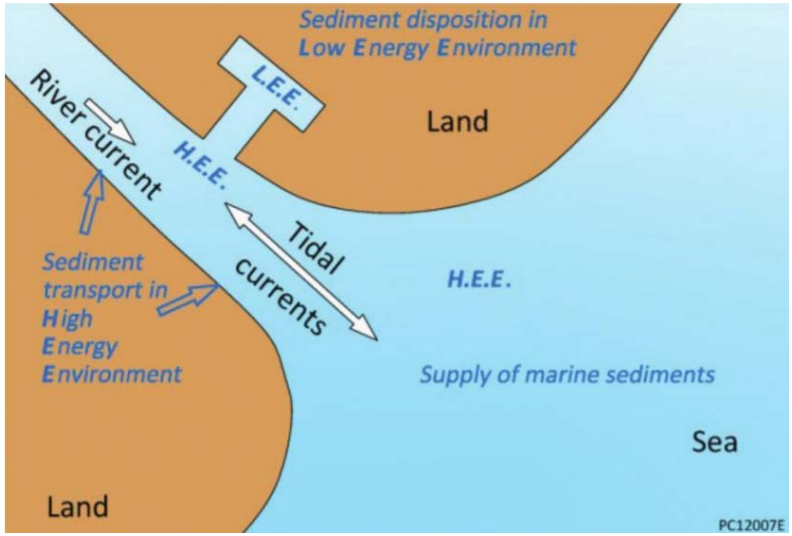
  - Small, efficient, autonomous and inexpensive dredging devices can change how the maintenance dredging is done over centuries.

- # Maintenance dredging and sedimentation

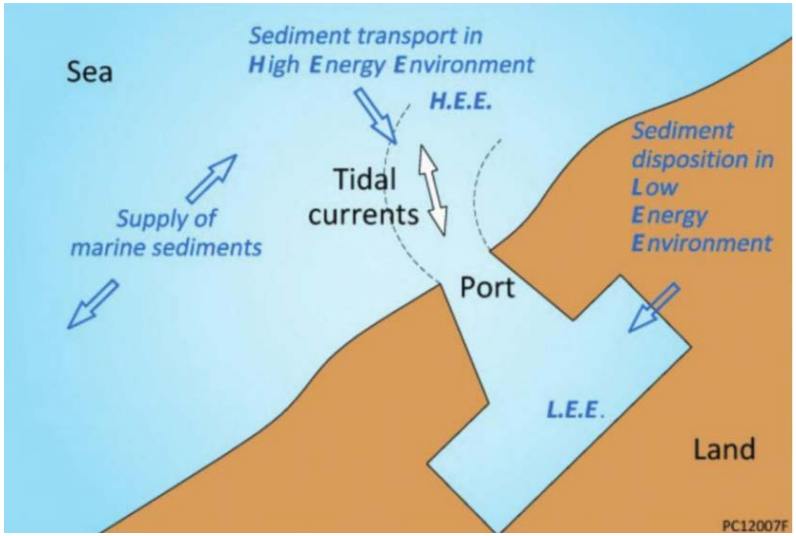
➢ Desirable water depths is requested;

➢ Maintenance dredging tends to be periodically;

➢ Nature tends to re-establish their natural balance;



Retrieved January 29, 2018 from source: PIANC



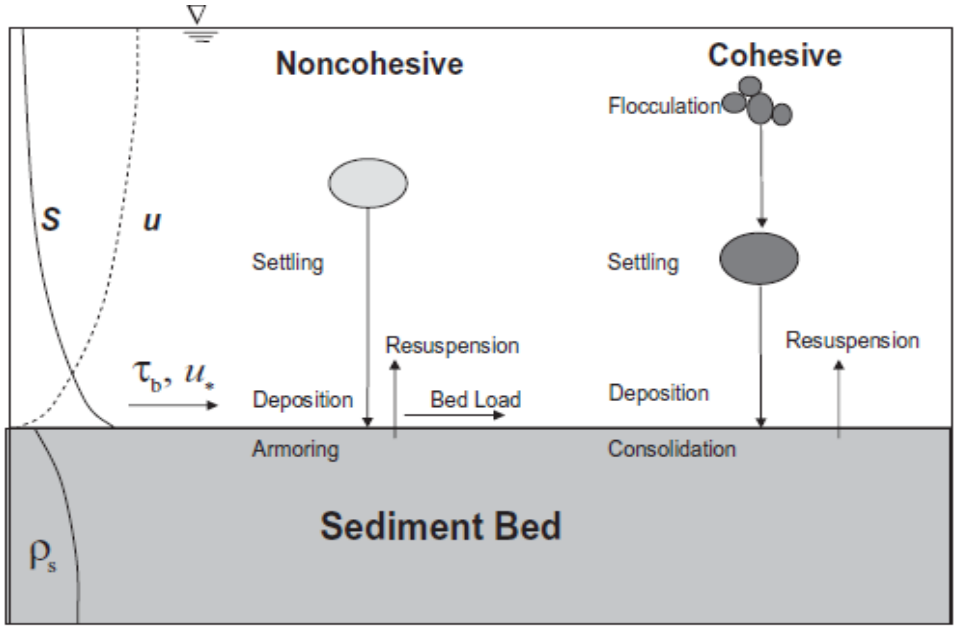
Retrieved January 29, 2018 from source: PIANC

- # Classification of sediments

➢ Properties vary depending on the composition of the material;

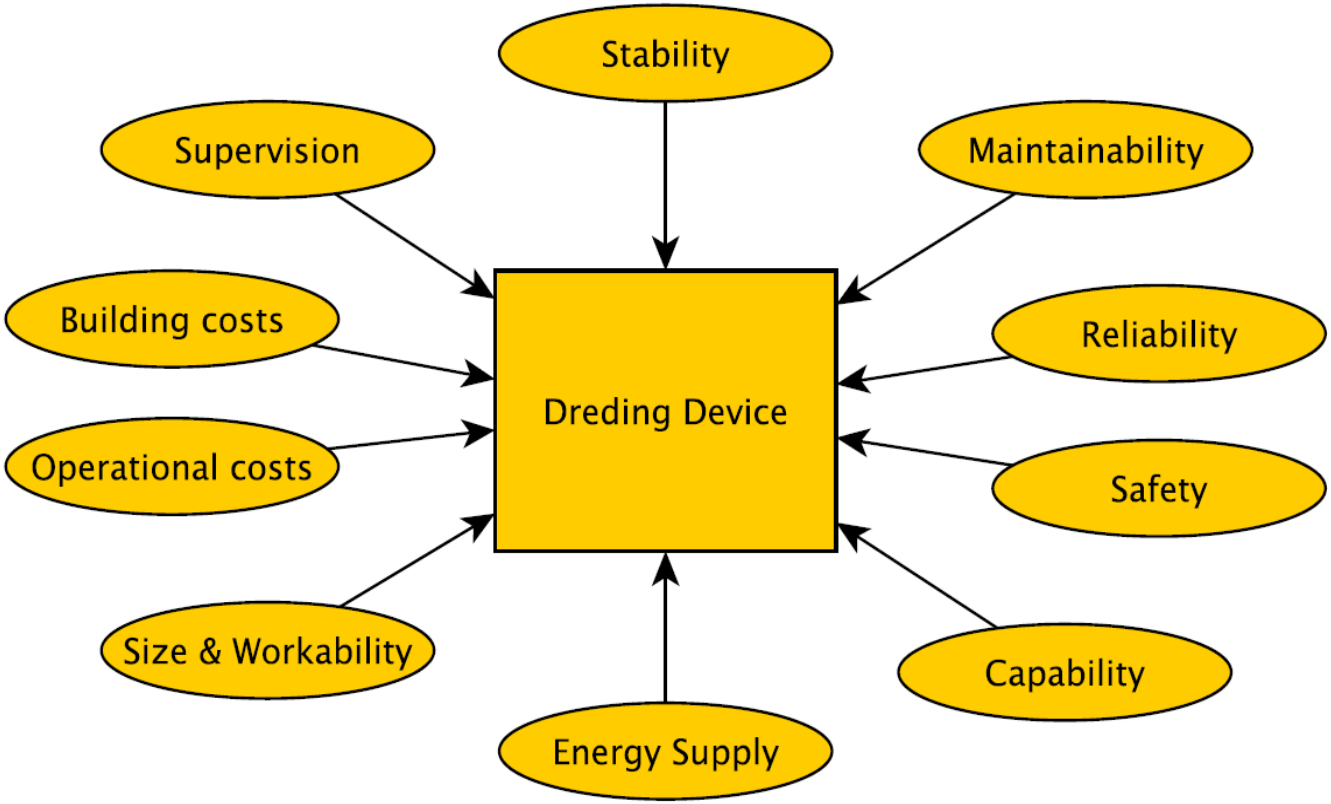
➢ Non-cohesive particles: no cohesive forces nor attraction forces. E.g.: silt and sand.

➢ Cohesive particles: Attraction forces is presented. E.g.: clay and organic material;



Retrieved January 29, 2018 from source: Zhen-Gang, Ji.

- Criteria diagram for dredging device

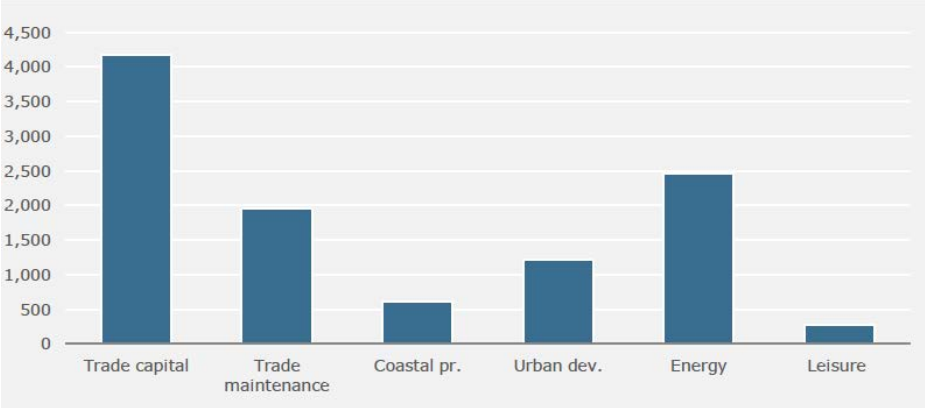


Retrieved January 29, 2018 from source: Author

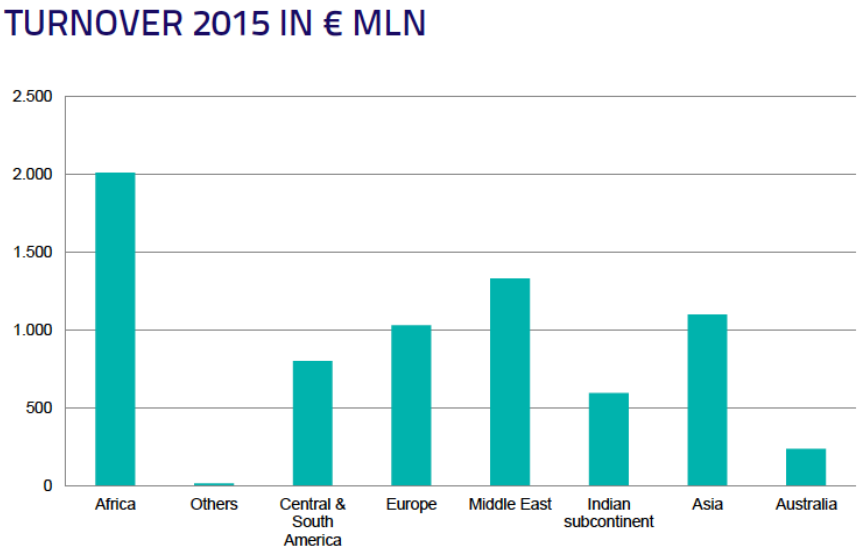
- # Global Dredging Market – EUR 11bn yearly

  - ## Closed Market – 43%
    - ✓ The United States
    - ✓ China

  - ## Open Market – 57%
    - ✓ Africa
    - ✓ Central & South America
    - ✓ Europe
    - ✓ Middle East
    - ✓ Asia
    - ✓ Oceania



Retrieved January 29, 2018 from source: IADC



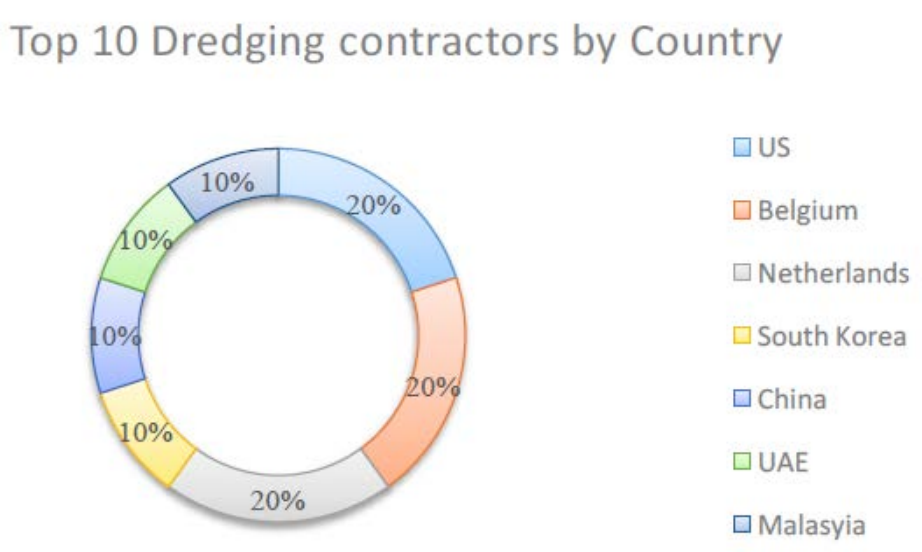
Retrieved January 29, 2018 from source: RABOBANK

- # Open Dredging Market – Major Companies

1. **Jan de Nul**
2. **Royal Boskalis Westminter**
3. **Van Oord**
4. **DEME**
5. **Chinese Harbour Engineering Company**
6. **Great Lakes Dredge and Dock**
7. **Weeks Marine Inc.**
8. **National Marine Dredging Company**
9. **Inai Kiara**
10. **Hyundai Engineering and Construction**

Country	Dredging companies
US	2
Belgium	2
Netherlands	2
South Korea	1
China	1
UAE	1
Malaysia	1

Retrieved January 29, 2018 from source: Author



Retrieved January 29, 2018 from source: Author

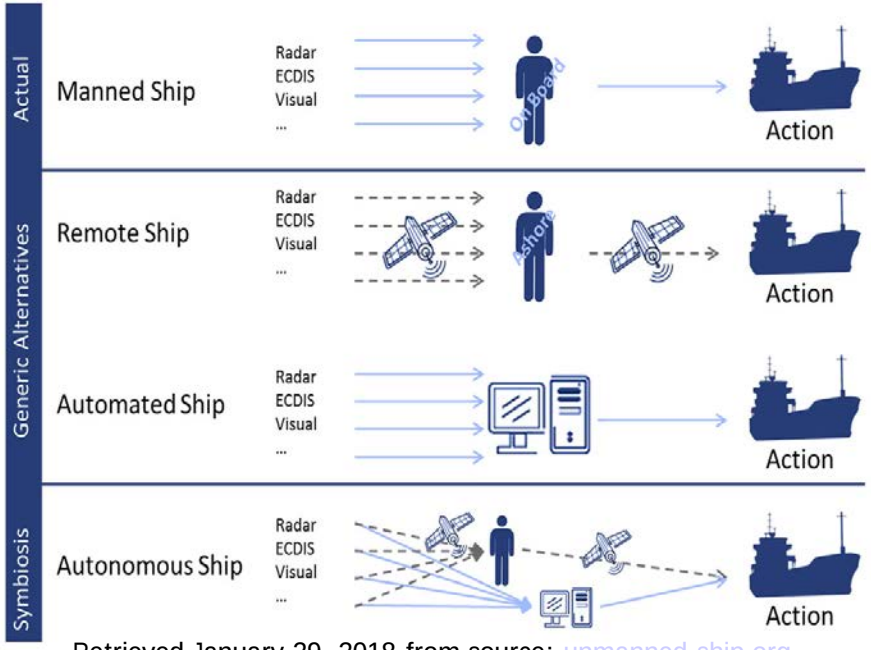
- # Parameters for feasibility study

  - ## Technical & Operational
    - ✓ Array of sensors, Cameras, LIDAR, RADAR, Ultrasound sensors;
    - ✓ Development of robust Artificial Intelligence;
    - ✓ Humans know how to build vessels;
    - ✓ Situation awareness;
    - ✓ Possibility to use reduced safety factor;
    - ✓ Communication architecture (Radio, Satellite);
    - ✓ Market has few players but is drawing attention year by year.
  - ## Legal
    - ✓ Current situation: No standards or rules, just territorial waters;
    - ✓ Drones since there is no crew on board;
    - ✓ Classification societies studying to develop new rules;
    - ✓ Llyod register – guidance for different level autonomy levels;
    - ✓ Workers and Unions not happy.
  - ## Financial
    - ✓ Initial investment higher due to “state-of-the-art technology” for communication, control system, auxiliary systems, automated mooring system, avoidance collision system and shore control center

Retrieved January 29, 2018 from source: Author

- Initiatives and researches under development

➢ MUNIN Project
- ✓ Stands for Maritime Unmanned Navigation through Intelligence in Networks;
- ✓ Just a concept of operation;
- ✓ Idealized for deep sea shipping;
- ✓ Seeking to prove feasibility

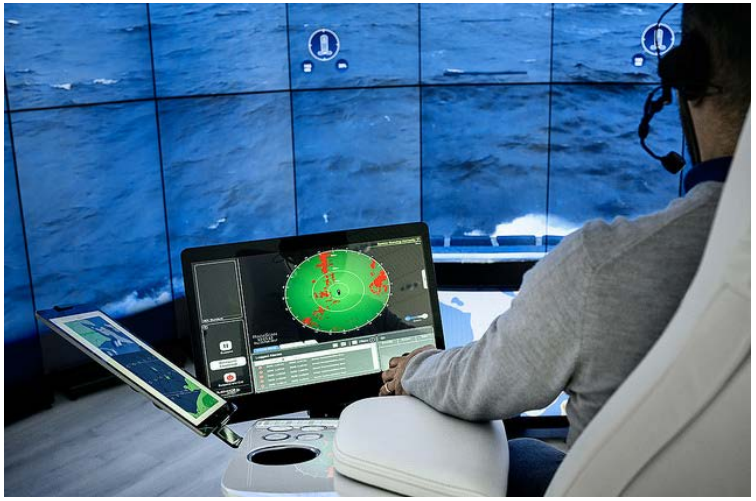


Retrieved January 29, 2018 from source: unmanned-ship.org

- Initiatives and researches under development

➢ AAWA Project
- ✓ Stands for Autonomous Waterborne Applications Initiative;
- ✓ Rolls-Royce company plays a main role;
- ✓ Focused on communication architecture;
- ✓ Main outcome is the idealized Remote Operating Centre (ROC)

Retrieved January 29, 2018 from source: Rolls-Royce



Retrieved January 29, 2018 from source: Rolls-Royce

- Initiatives and researches under development

➢ DNV GL The ReVolt
- ✓ Innovative concept for container feeder;
- ✓ Fully-battery powered;
- ✓ Ballast free design;
- ✓ Dimensions: 60 x 15m;
- ✓ Service speed: 6knots;
- ✓ Operational range: 100nm.

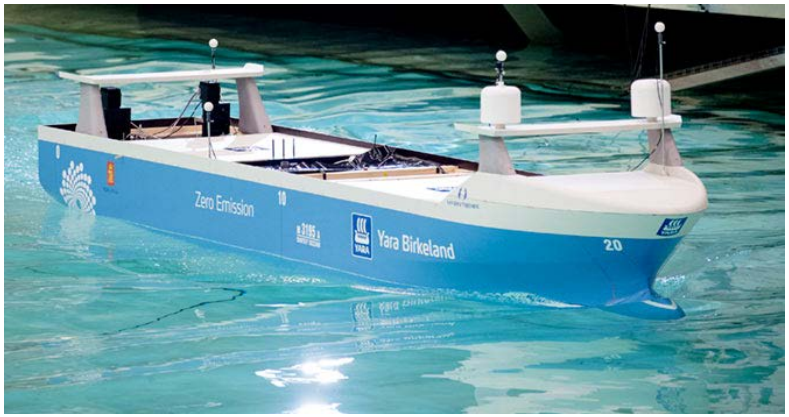
Retrieved January 29, 2018 from source: Blue Bird Marine Systems

Retrieved January 29, 2018 from source: Blue Bird Marine Systems

- Initiatives and researches under development

➢ Yara Birkeland
- ✓ Programmed to be delivery by the end of 2018;
- ✓ Fully electric;
- ✓ Designed to sail in Norwegian territorial waters;
- ✓ Operational range: 12 nm;
- ✓ Scale model undergoing tank tests in Norway.

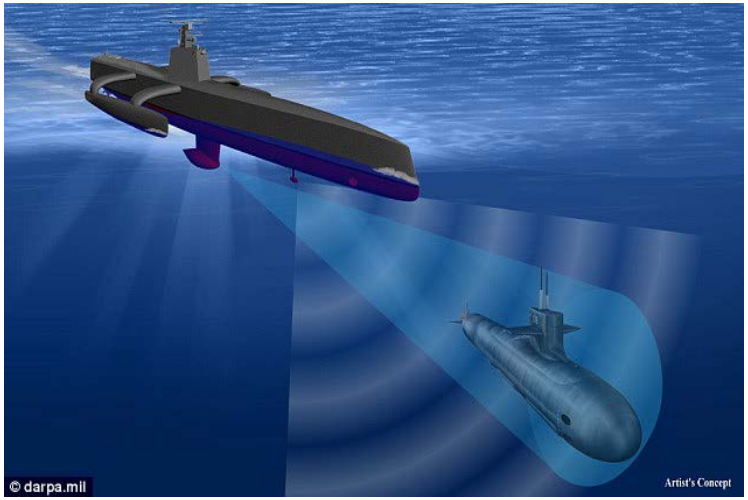
Retrieved January 29, 2018 from source: Kongsberg



Retrieved January 29, 2018 from source: Kongsberg

- Initiatives and researches under development

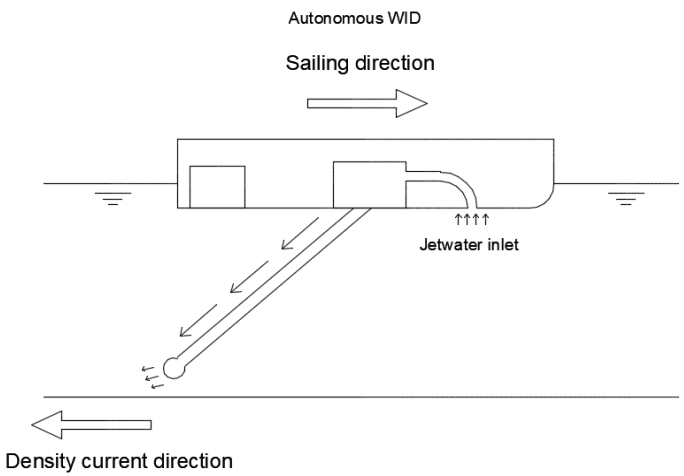
➢ DARPA Sea Hunter
- ✓ Submarine hunter;
- ✓ Trimaran hull;
- ✓ Diesel propulsion;
- ✓ Long endure;
- ✓ Main dimensions: 40 m long
- ✓ Service speed: 27 knots



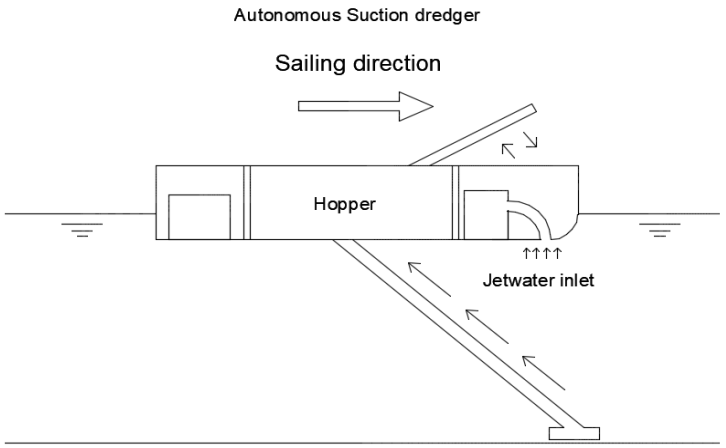
Retrieved January 29, 2018 from source: Osborn, Kris.

Retrieved January 29, 2018 from source: Szoldra, Paul.

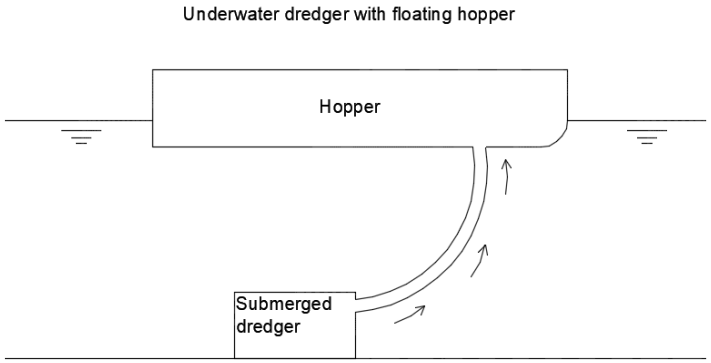
- Proposed concepts



Autonomous water injection dredging device. Retrieved January 29, 2018 from source: Author



Autonomous suction dredging device. Retrieved January 29, 2018 from source: Author



Autonomous submerged walking dredger with floating hopper. Retrieved January 29, 2018 from source: Author

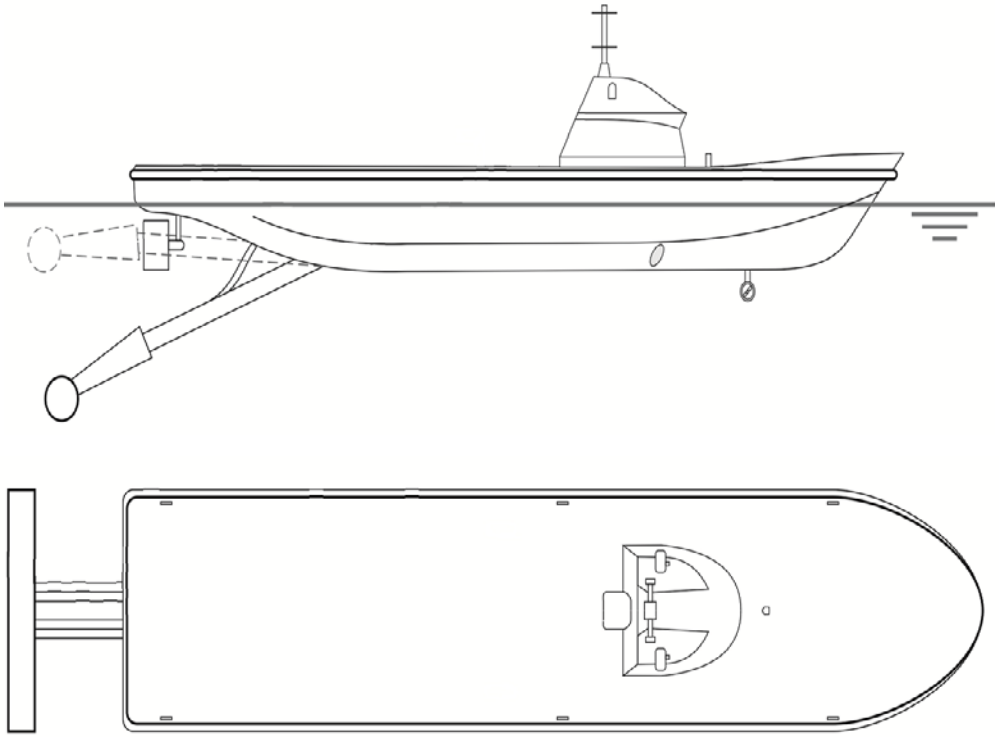
- Multi-criteria Analysis

ID	Criterion	Weight Factor	AWID	Suction	Underwater
1	Stability	5	9	9	6
2	Maintainability	4	8	8	6
3	Reliability	5	9	7	5
4	Safety	5	9	8	7
5	Capability	4	7	9	9
6	Energy supply	2	9	9	6
7	Size & Workability	5	8	7	6
8	Operational costs	5	10	7	7
9	Building costs	4	8	7	6
10	Supervision	3	8	8	8
	Total weighted score		**855**	781	655
			1st	2nd	3rd

- Main Particulars and General Arrangement

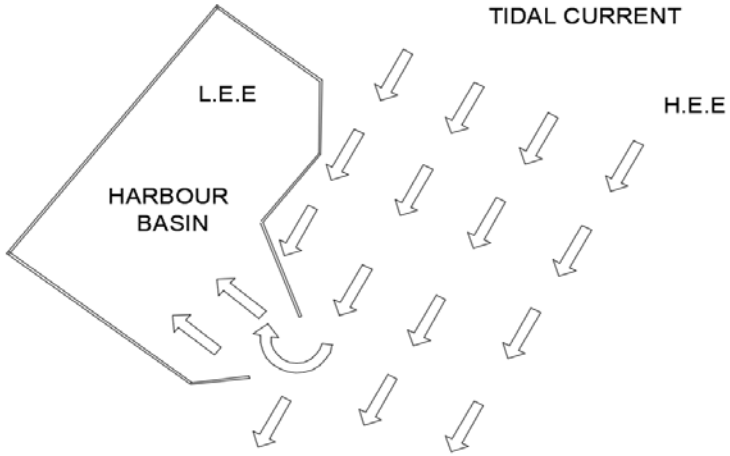
Energy requirement	
Jetting Power	310 kW
Propulsion power	2*95 kW
Total	500 kW
Main particulars	
Length Overall	15 m
Beam	4,5 m
Depth	1,8 m
Draft	1,6 m
Jet beam dimensions	
Jet bar beam	4,5 m
Maximum dredge depth	20 m

Retrieved January 29, 2018 from source: Author



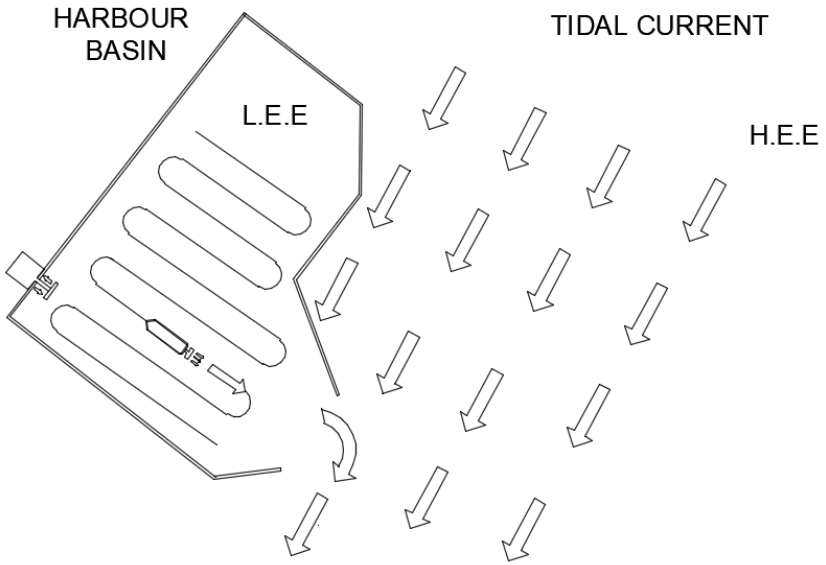
Retrieved January 29, 2018 from source: Author

- Operational concept
  - Small harbor basin directly at the sea;
  - L.E.E – Low Energy Environment;
  - H.E.E – High Energy Environment;
  - Expected net production: 450 m3/hour;
  - Service speed: 1 kn;
  - Moving speed: 10 kn;
  - Operational range: 15 km;
  - Five different operating modes;
  - Automated mooring system;
  - Shore control center.

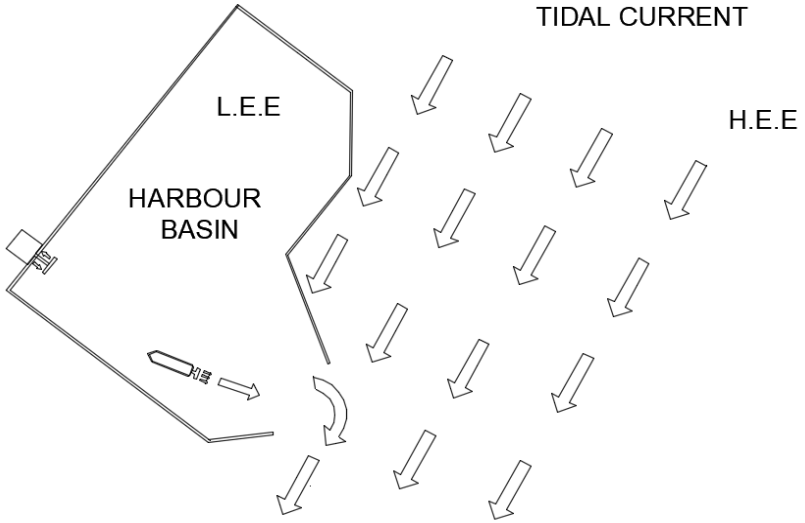


Mud sedimentation scheme in harbor basin.
Retrieved January 29, 2018 from source: Author

- Operating modes
  - Remote-controlled mode
  - **Waypoint mode**
  - **Autonomous mode**
  - Swarm mode
  - Emergency mode

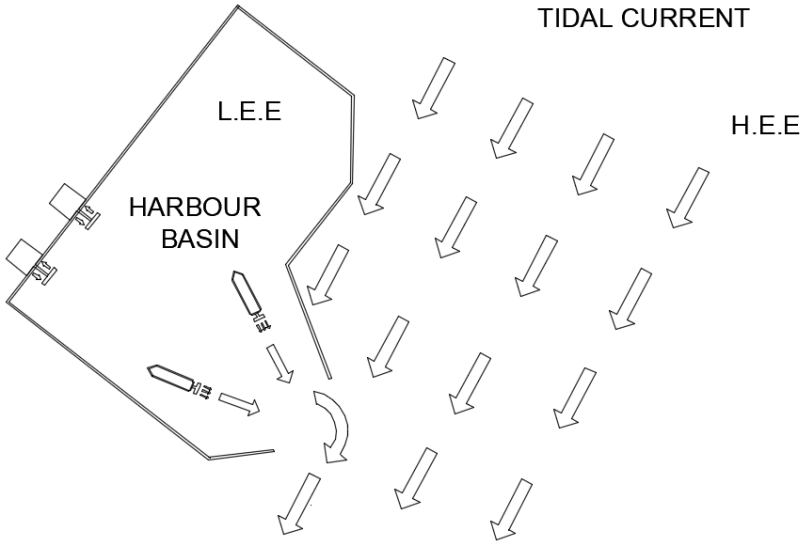


Waypoint mode representation. Retrieved January 29, 2018 from source: Author

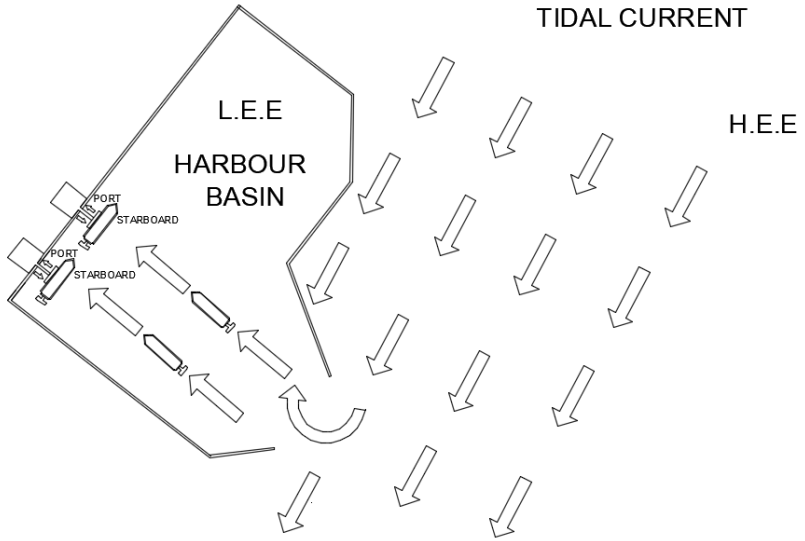


Autonomous mode representation. Retrieved January 29, 2018 from source: Author

- Operating modes
  - Remote-controlled mode
  - Waypoint mode
  - Autonomous mode
  - **Swarm mode**
  - **Emergency mode**



Swarm mode representation. Retrieved January 29, 2018 from source: Author



Emergency mode representation. Retrieved January 29, 2018 from source: Author

- Conclusions
  - Preliminary outcome is just The tip of the iceberg;
  - Proof of concept is necessary;
  - Lack of regulations and literature;
  - There is still a lot discussion about the use of artificial intelligence to take over human tasks;
  - Open dredging market is ruled by major companies who are not interested in simplifying the process;
  - Some stakeholders are still skeptical about unmanned navigation.

- Recommendations
  - Sounds interesting for startups willing to change to change the dredging contract standards;
  - Further studies are important to figure out what other applications are suitable for unmanned navigation;
  - Following student should focus on development of situational awareness system.

Thank you!

http://www.wildoceanfilm.com/marketing/images/photos/marinelife/Big%20Ship.jpg