# Identified Hull Cleaning Robots

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WPI

# DISCLAIMER

This article was prepared by Andrew Curran, Evan King, Carolyn Lowe and Brendan O’Connor in their personal capacity.

The opinions expressed in this article are the authors' own and do not reflect the view of the United States Coast Guard, the Department of Homeland Security or the United States government.

Furthermore, data presented here is not an exhaustive or exclusive list. There may be more technologies, and more data on existing ones.

# FOREWORD

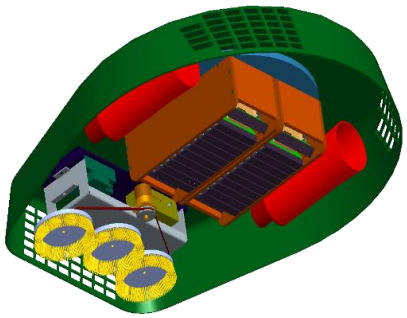
This binder was created by Andrew Curran, Evan King, Carolyn Lowe and Brendan O'Connor during their time working at the United States Coast Guard, under the supervision of Debbie Duckworth.

This binder details the 16 hull cleaning robots that the WPI students were able to identify and research over their eight weeks working with the USCG.

## Contents

# GreenSea Robotic Hull Cleaner

**Raytheon Company - Waltham, Massachusetts, United States**

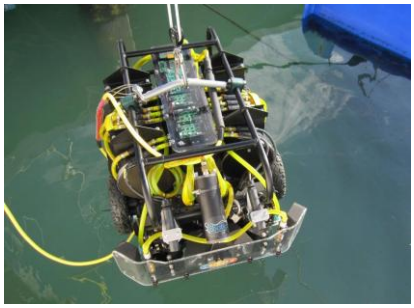


The development for Raytheon's hull cleaning robot is no longer active. GreenSea was designed to be able to be used while a ship is underway. By using extremely powerful neodymium magnets, it is able to remain attached to the hull of a ship at speeds up to 26 knots. In an effort to simplify use, the robot charges its battery using turbines attached to the robot. Apart from periodic maintenance, the robot is completely autonomous and can react to dangerous conditions.

| | |
|---|---|
| Status | Terminated |
| Contact | Successful |
| Cost | $400,000 |
| Grooming Speed | 1,500 $m^2$/ h |
| Grooming System | Brushes using ultrasonic action |
| Usable While Underway | Yes |
| Dimensions | 6 x 36 x 24 in |
| Weight | 225lbs |
| Max Depth | 1500 |
| Mean Time to Failure | 5 year |
| Holding System | Neodymium magnet track system |
| Holding Force | Holding pressure/force totaling up to 2,250 lbs |
| Sensors Included | Multi-axis inertial sensor, angular sensor locator |
| Filter | Yes |
| Tethered | No |
| Operation Type | Autonomous |

# HullBUG

**SeaRobotics Corporation - Stuart, Florida, United States**



The Hull Bio-Inspired Underwater Grooming System (HullBUG) is a hull cleaner being developed by SeaRobotics and the Office of Naval Research. HullBUG is a platform that supports a diverse set of modules. It's highly adaptable and is not limited to hull cleaning. Hull integrity inspection and marine research are obvious alternate missions, though more exist.

| | |
|---|---|
| Status | Development and testing |
| Contact | Successful |
| Cost | Base price $160,000 – options available |
| Grooming Speed | 400-600 $m^2$/h |
| Grooming System | Soft/hard brushes and dual dome jet based operatic modeler |
| Usable While Underway | No |
| Dimensions | 75 x 150 cm |
| Weight | 55kg |
| Max Depth | Unknown |
| Mean Time to Failure | 5 years |
| Holding System | Magnetic system or negative pressure for naval ships |
| Holding Force | 130 lb |
| Sensors Included | Biofilm detector, Compass, Attitude, Video With LED, Illumination, High Frequency Sonar, Fiber Optic Gyro, Imaging/Profiling, Hull Plate, Thickness Sensing, Encoders, Health Sensors, and Additional Sensors Possible |
| Filter | Yes |
| Tethered | No |
| Operation Type | Autonomous and semiautonomous |

# HullWiper

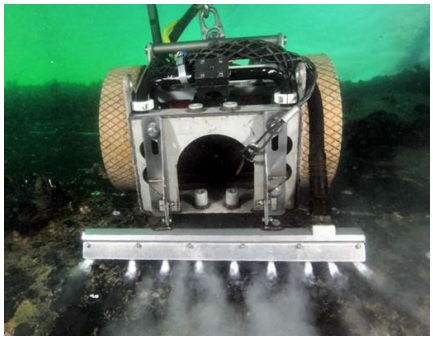
**Gulf Agency Company EnvironHull -**
**Dubai, United Arab Emirates**


HullWiper is a hull cleaner designed by Gulf Agency Company EnvironHull. Currently 15 units have been produced, and are in use in 12 ports across the world. A support platform is required for the HullWiper. The support platform provides power and water pressure, which is used to clean the surface of the hull. The filter is able to handle 50 cubic meters of fouling per hour.

| | |
|---|---|
| Status | In use |
| Contact | Successful |
| Cost | $1,000,000 |
| Grooming Speed | 2000 $m^2$/h |
| Grooming System | 3 cleaning discs that pump saltwater |
| Usable While Underway | No |
| Dimensions | 330 x 170 x 85 cm |
| Weight | 1200 kg |
| Max Depth | 100 m |
| Mean Time to Failure | Unknown |
| Holding System | Negative Pressure system |
| Holding Force | Unknown |
| Sensors Included | Camera, Depth sensor, oil pressure sensor, level oil sensor, and water pressure sensor |
| Filter | Yes |
| Tethered | Yes |
| Operation Type | Manual |

# Magnetic Hull Crawler

**Technip Cybernetix - Marseille, France**

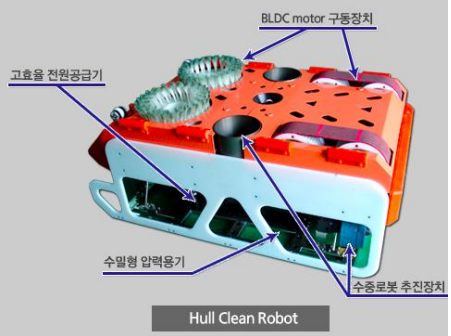


Magnetic Hull Crawler or MHC was designed with the commercial shipping industry in mind, as well as the offshore oil and gas industries. The system has been in use since 2005, and was originally designed for the purpose of hull inspection. In addition to hull cleaning, MHC can provide detailed models of hulls, pipelines and rigs. This allows users to detect issues The cleaning system is able to reach up to 1000 bar.

| | |
|---|---|
| Status | In use |
| Contact | Complete |
| Cost | Highly variable |
| Grooming Speed | 100-200 $m^2$/h |
| Grooming System | Pressure washer |
| Usable While Underway | Up to 2-3 knots |
| Dimensions | 600 x 500 x 500 mm |
| Weight | 65 kg without payload. 100 kg with payload |
| Max Depth | 50m depth rating |
| Mean Time to Failure | Replace nozzles every 24-48 hours' worth of use |
| Holding System | Magnets on undercarriage |
| Holding Force | 300-400 kg |
| Sensors Included | Cameras, Analog UT probes, CP reading tool, IMU & Depth sensor. |
| Filter | No |
| Tethered | Yes |
| Operation Type | Manual |

# Underwater Robot

**Daewon Systems Co Ltd - Shiheung South Korea**

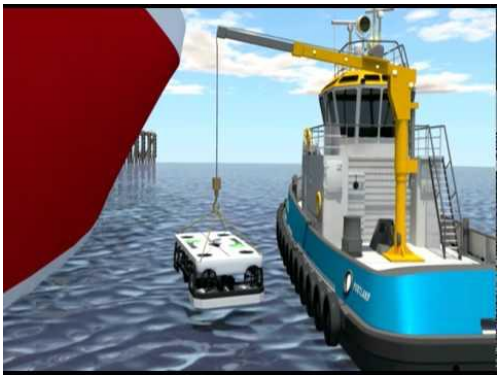



The goal of Daewon System Co Ltd was to develop a cleaning platform capable of real time underwater location tracking. The Underwater Robot can be used on LNG tankers. It has the power to clean moss, algae and barnacles in close contact to the vessel.

| | |
|---|---|
| Status | Development |
| Contact | Successful |
| Cost | $400,000 |
| Grooming Speed | 200 $m^2$ /h when cleaning barnacles, 630$m^2$/h when cleaning moss |
| Grooming System | Brushes |
| Usable While Underway | No |
| Dimensions | 170 x 100 x 68 cm |
| Weight | 315 kg |
| Max Depth | Unknown |
| Mean Time to Failure | 1000 hours |
| Holding System | Thrusters |
| Holding Force | Unknown |
| Sensors Included | PRS-8080 camera, depth sensor, USBL, DVL, IMU, and DGPS |
| Filter | Unknown |
| Tethered | Unknown |
| Operation Type | Autonomous |

# CleanHull

**Cleanhull Ltd – Limassol, Cyprus**



CleanHull is designed for use on larger ships. CleanHull currently is in ports such as Mongstad, Karsroe, Goteborg as well as others.

| | |
|---|---|
| Status | In use |
| Contact | Contacted, awaiting potential release of information |
| Cost | Unknown |
| Grooming Speed | 800-1000 $m^2$/h |
| Grooming System | High pressure water |
| Usable While Underway | Able to operate in difficult conditions |
| Dimensions | Unknown |
| Weight | Unknown |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | Turbines |
| Holding Force | Unknown |
| Sensors Included | Cameras |
| Filter | Yes |
| Tethered | Yes |
| Operation Type | Semiautonomous |

# Fleet Cleaner

**Fleet Cleaner - Leeuwarden, The Netherlands**

The Fleet Cleaner hull cleaning robot was developed for vessels in the shipping industry. It uses high powered water jets to remove and capture fouling.

| | |
|---|---|
| Status | Testing |
| Contact | Attempted |
| Cost | Unknown |
| Grooming Speed | 1,200 $m^2$/h |
| Grooming System | High powered water jets |
| Usable While Underway | No |
| Dimensions | 1.8 x 1.8 x 0.6 m |
| Weight | Unknown |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | Magnetic |
| Holding Force | Unknown |
| Sensors Included | Unknown |
| Filter | Yes |
| Tethered | Yes |
| Operation Type | Manual |

# Hull Surface Treatment

**Commercial Diving Services Pty LTD - Australia**


Hull Surface Treatment (HST) uses thermal shock instead of brushes or water jets. This cleaning system heats seawater to roughly 70°C and kills fouling using heated water. There is no need for a filter. When the ship reaches open waters, the dead fouling is washed away by the waves. The compact design of the HST allows it to be used on any surface, including sea chests and propellers. HST is unique because it claims to be able to cover 100% of the target hull. However, it is unable to clean any kind of hard fouling.

| | |
|---|---|
| Status | In use |
| Contact | Attempted |
| Cost | Roughly 15% of fuel savings |
| Grooming Speed | Unknown |
| Grooming System | Thermal Shock |
| Usable While Underway | No |
| Dimensions | Unknown |
| Weight | Unknown |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | Magnets |
| Holding Force | Unknown |
| Sensors Included | Unknown |
| Filter | Not needed |
| Tethered | Yes |
| Operation Type | Manual |

# Hullbot

**Hullbot Pty LTD - Rotterdam, Netherlands / Sydney, Australia**


Hullbot is a hull cleaning robot primarily designed for use on yachts. It uses disk shaped rotating cleaning pads to clean vessels while at anchor. The Hullbot is designed to do a cleaning once every four hours. It uses a pre-loaded model of the yacht in order to determine its orientation as well as the percentage of surface area cleaned.

| | |
|---|---|
| Status | Development and testing |
| Contact | Attempted |
| Cost | Unknown |
| Grooming Speed | Unknown |
| Grooming System | Cleaning rotating disks |
| Usable While Underway | No |
| Dimensions | Unknown |
| Weight | Unknown |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | 3 thrusters |
| Holding Force | Unknown |
| Sensors Included | Unknown |
| Filter | No |
| Tethered | Yes |
| Operation Type | Currently manual with controller, developing autonomous control system |

# Hulltimo

**Hulltimo - France**

Hulltimo is designed primarily for sailboats and motorboats. It comes equipped with a camera and remote control with a display. The robot must be controlled by a trained operator, and is able to clean a 34-foot boat in approximately an hour. The suction system installed on the robot allows it to move along sharp angles on the hull surface.

| | |
|---|---|
| Status | Suspected to be no longer in business- website is down |
| Contact | Attempted |
| Cost | $3,105 |
| Grooming Speed | Unknown |
| Grooming System | 2 brushes, one roller made of polyamide |
| Usable While Underway | No |
| Dimensions | 51 x 67 x 37 cm |
| Weight | Unknown |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | Suction system |
| Holding Force | Unknown |
| Sensors Included | Camera |
| Filter | Debris collecting filter |
| Tethered | Yes |
| Operation Type | Manual |

# KeelCrab Sail One

**Aeffe s.r.l. - Bulgarograsso, Italy**

The KeelCrab Sail One was designed to clean sail boats, yachts, and maxi yachts. The robot is designed to not only clean hulls, but to also perform hull inspections.

| | |
|---|---|
| Status | In use |
| Contact | Attempted |
| Cost | € 3,299 |
| Grooming Speed | 1.5 $m^2$/min |
| Grooming System | Turbine vacuum, rubber, and nylon brushes |
| Usable While Underway | No |
| Dimensions | 42.5 x 42.5 x 32 cm |
| Weight | 9.5 kg |
| Max Depth | Unknown |
| Mean Time to Failure | Guarantee 24 months or 500 hours of use |
| Holding System | Vacuum force driven by turbine |
| Holding Force | Unknown |
| Sensors Included | High-resolution underwater camera IP68 |
| Filter | Yes |
| Tethered | Yes |
| Operation Type | Manual |

# M6 Sub sea Cleaning Tool

**Vertidrive - Ridderkerk, The Netherlands**

The M6 Subsea Cleaning Tool is a manually operated device primarily made for use on floating productions, storage and offloading units (FPSO), or off shore working platforms. The M6 is built with a swing boom with a 2-meter reach. Water is pumped through the boom to remove fouling in a wide radius around the robot.

| | |
|---|---|
| Status | In use |
| Contact | Attempted |
| Cost | Unknown |
| Grooming Speed | Unknown |
| Grooming System | High pressure water nozzles |
| Usable While Underway | Unknown |
| Dimensions | 750 x 750 x 350 mm |
| Weight | 85 kg |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | Magnets |
| Holding Force | Unknown |
| Sensors Included | Unknown |
| Filter | Unknown |
| Tethered | Yes |
| Operation Type | Manual |

# Remora

**University of Southampton - Southampton, England**

Remora is a robot in development by students at the University of Southampton. The goal of this project is to design an autonomous robot, with the ability to function and clean a ship's hull while a ship is in motion. Remora uses a hydrodynamic shell that allows the robot to function at up to 8 knots. With upgrades and further testing the students believe the system will be able to handle 15 knots.

| | |
|---|---|
| Status | Development |
| Contact | Attempted |
| Cost | Unknown |
| Grooming Speed | Unknown |
| Grooming System | Unknown |
| Usable While Underway | Up to 8 knots |
| Dimensions | Unknown |
| Weight | Unknown |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | Magnets |
| Holding Force | 639 kg |
| Sensors Included | Ultrasonic Sensors |
| Filter | Unknown |
| Tethered | Unknown |
| Operation Type | Autonomous |

# ROVING BAT

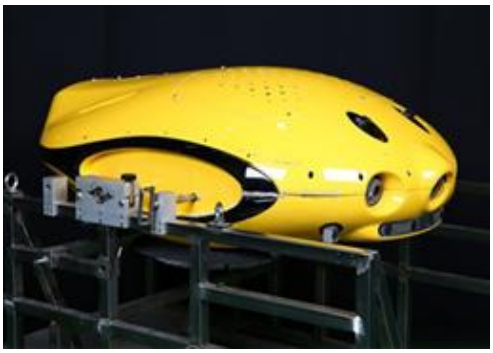
**ECA Group - La Garde, France**


The ROVING BAT by ECA group is a hull cleaning robot built for FPSO and oil rigs. ROVING BAT can autonomously connect to the hull of the ship using four propellers. ROVING BAT is also able to perform a hull inspection while it is removing biofouling.

| | |
|---|---|
| Status | In use |
| Contact | Attempted |
| Cost | Unknown |
| Grooming Speed | Unknown |
| Grooming System | Uses either hydro-jetting or a brushing system |
| Usable While Underway | Unknown |
| Dimensions | 41” x 41” x 17” |
| Weight | 265lb |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | 6 thrusters, 2 sets of motorized tracks |
| Holding Force | Unknown |
| Sensors Included | Sensors for accelerometer, temperature, water ingress, amperage, positioning |
| Filter | Unknown |
| Tethered | Yes |
| Operation Type | Semiautonomous |

# Underwater Hull Cleaning Robot

**Samsung Heavy Industries – Seoul, South Korea**



Samsung Heavy Industries' (SHI) hull cleaning robot is designed to clean SHI's LNG carriers during and immediately after production. While we were able to make contact with Samsung, they chose not to release any information on their hull cleaner.

| | |
|---|---|
| Status | Unknown |
| Contact | Successful, no information given |
| Cost | Proprietary |
| Grooming Speed | Proprietary |
| Grooming System | Proprietary |
| Usable While Underway | Proprietary |
| Dimensions | Proprietary |
| Weight | Proprietary |
| Max Depth | Proprietary |
| Mean Time to Failure | Proprietary |
| Holding System | Proprietary |
| Holding Force | Proprietary |
| Sensors Included | Proprietary |
| Filter | Yes |
| Tethered | Proprietary |
| Operation Type | Proprietary |

# (No Name)

**Carnegie Mellon University – Pittsburgh, Pennsylvania, United States**

The robot was developed by students at Carnegie Mellon University during an internship at Tsuneishi Shipbuilding Company's headquarters in Fukuyama Japan. Little is known about this robot, and little was found on the project. All that is known is that they were given three tasks: To develop a retrofit sensor network, to develop a welding robot, and to develop a ship hull cleaning robot.

| | |
|---|---|
| Status | Unknown |
| Contact | Attempted |
| Cost | Unknown |
| Grooming Speed | Unknown |
| Grooming System | Unknown |
| Usable While Underway | Unknown |
| Dimensions | Unknown |
| Weight | Unknown |
| Max Depth | Unknown |
| Mean Time to Failure | Unknown |
| Holding System | Unknown |
| Holding Force | Unknown |
| Sensors Included | Unknown |
| Filter | Unknown |
| Tethered | Unknown |
| Operation Type | Unknown |

## Acknowledgments:

We would like to take the time to thank and acknowledge a number of people. Without them, this project would not have been possible. We would like to thank our sponsoring agency, the United States Coast Guard (USCG) for providing us with this amazing opportunity. Specifically, we would like to thank the Office of Environmental Standards (OES-3) and the Marine Safety Center (MSC). The following people have been instrumental and essential to our project.

First of all, Debbie Duckworth, our project liaison without whom, this project would not have been possible. Debbie's unwavering support from the beginning has allowed us to produce the best possible product. From helping with security and IT issues to providing insight on our project and its objectives, Debbie has coordinated all areas of our project and guaranteed that we had the resources we needed. Commander Meridena Kauffman was a driving force for our project. Her willingness to donate her time to offer advice and support has not gone unnoticed. Lieutenant Anna Moorman of MSC has worked to organize our project from day one. Furthermore, she coordinated a visit to Coast Guard Yard for our team. Jae-Won Jones volunteered to help with translating a call with Korea. Without her help, the call would have been impossible. John Morris of OES has been immeasurably helpful at all times. His willingness to lend a hand, even though he's never been required to, has helped our project greatly. Special thanks should be given to Captain Scott Kelly for his professional guidance and advice.

We would like to express our appreciation to Rear Admiral Paul F. Thomas, for taking time out of his busy schedule to take an interest in our group and to support our project.

Our group would like to extend gratitude to Brain Ellis for helping us gain a better understanding of naval design, as well as Lieutenant Commander Jason Kling for his assistance regarding type approval of shipboard systems.

Thanks to our advisors from Worcester Polytechnic Institute, Professor Stephen McCauley and Professor James Hanlan for their assistance and revisions on our report.

Additionally, we would like to offer gratitude to the companies that directly assisted our collection of data on the various hull cleaning robots:

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- Daewon Systems Co Ltd
- Technip Cybernetix

We would also be remiss if we did not mention Residence Inn by Marriott at Dupont Circle for housing us for the duration of our project. Their staff has been unilaterally friendly and helpful, even when our requests were beyond what a normal hotel guest might ask.

Finally, we would like to thank Worcester Polytechnic Institute for the unique opportunity to work with the United States Coast Guard (USCG).

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