HIERARCHY OF PROTEI

WILD ROBOTS

Forword

This report will present you with an overview of the process we went through while working on the Wild Robots project at Next Nature. Each process phase will be addressed individually and will be backed up by visuals.

We will start with the project description as we received it at the beginning of the semester. This will provide you with the project goal, but also with some information on the client and the communication we had with them. This will be backed up by an overview of the early project phase in which our goals/ ideas/vision on the project were changed a few times.

This phase of the project was ended by writing a personal design brief which provides you with our goals and core vision on the project. The design brief will be addressed separately as it provided us with a clear vision and planning for the project. From the design brief we will walk through the process phases and we will work towards the concept.

Information

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Project: Wild Robots

Theme: Next Nature

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Introduction

Robots have been around for decades, yet so far they have primarily operated in a professional, laboratory or home setting. New technologies provide us with lightweight & self-sustainable power sources and more durable material mechanics. These new technological improvements will benefit the new generations of robots that we design. It is because of this that we anticipate the rise of a new breed of ‘wild robots’: robots that autonomously populate and operate within the worlds ecosystems.

Will the woods one day be populated by fire-fighting robots that search & extinguish fires? Will the plastic debris and spilled oil in our oceans be cleaned by robotic garbage collectors? Will minefields become pro-active and deadlier than ever? Or will our robotic fellow species watch over us with loving grace?

Wild robotic systems bring us opportunities as much as questions. In the current incarnation of the project, we have worked on an autonomous sailing robot designed to clean oil-spills in the oceans. Goal of the project is to create a functional system as well as answer some of the general questions like:

How can they successfully intervene in existing ecosystems? How will they communicate with existing entities (e.g. animals) in these ecosystems? How will they communicate amongst each other? And how autonomous do we allow them to be?

Project Description

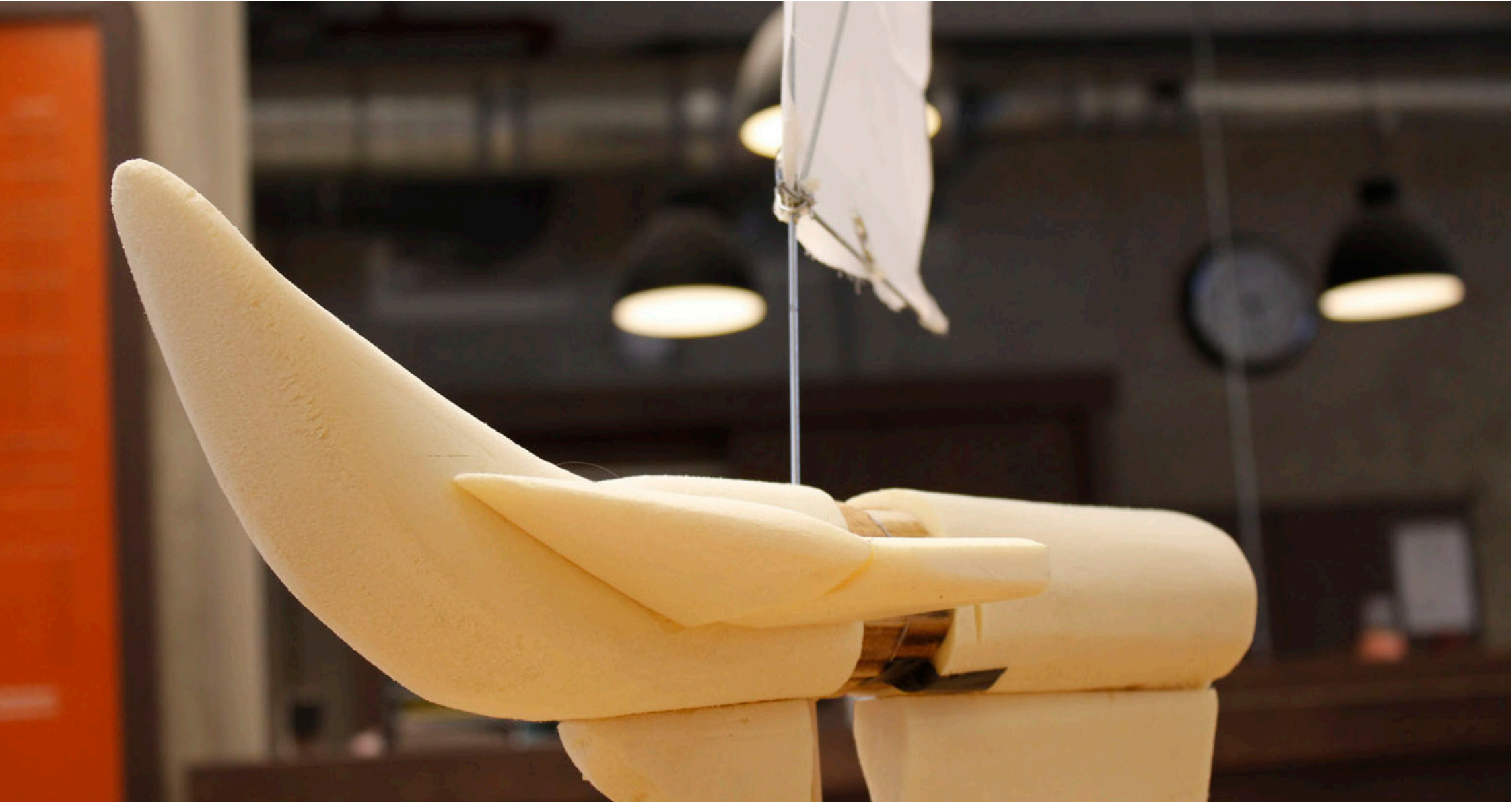
For the course of this project the team has worked with a client named Protei. Protei is an open source project that is led by a small group of individuals. These individuals share the vision of deploying autonomous sailing drones in the world's oceans and seas. These sailing drones will have the primary task of finding and collecting oil that is spilled all over the world. The drones will collect the oil with absorbing tails that are attached to the back of the drone. One of the main advantages of Protei is that each drone works autonomously. Because of this there is no longer a need for manned skimmer boats to collect the oil. Personnel of these boats get in to contact with rough oil each day which is very bad for their health. Other advantages of autonomous drones are: low cost development, improving oil detection, optimizing efficiency, eco-friendly and they can operate in any weather condition.

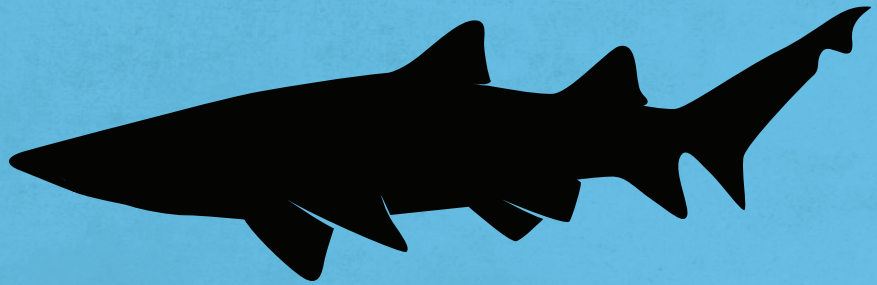
For Protei to work efficiently there are a lot of points that have to be addressed. The drones will have to move upwind, because oil spreads down wind and it follows the water current. There is need of a large group of Protei drones to efficiently collect the oil. These large groups will have to work together.

This teamwork should come from the behavior and the rules that are defined for this swarm of drones. Finally these robots will have to be produced. Because Protei is an open source project, the production and development of the drones will be done by individuals all over the world that are interested in helping the cause of Protei.

As students of the Wild Robot project we also have interest in this cause. And during the course of this semester we have worked on the first steps of the collaboration between the Eindhoven University of Technology and Protei.

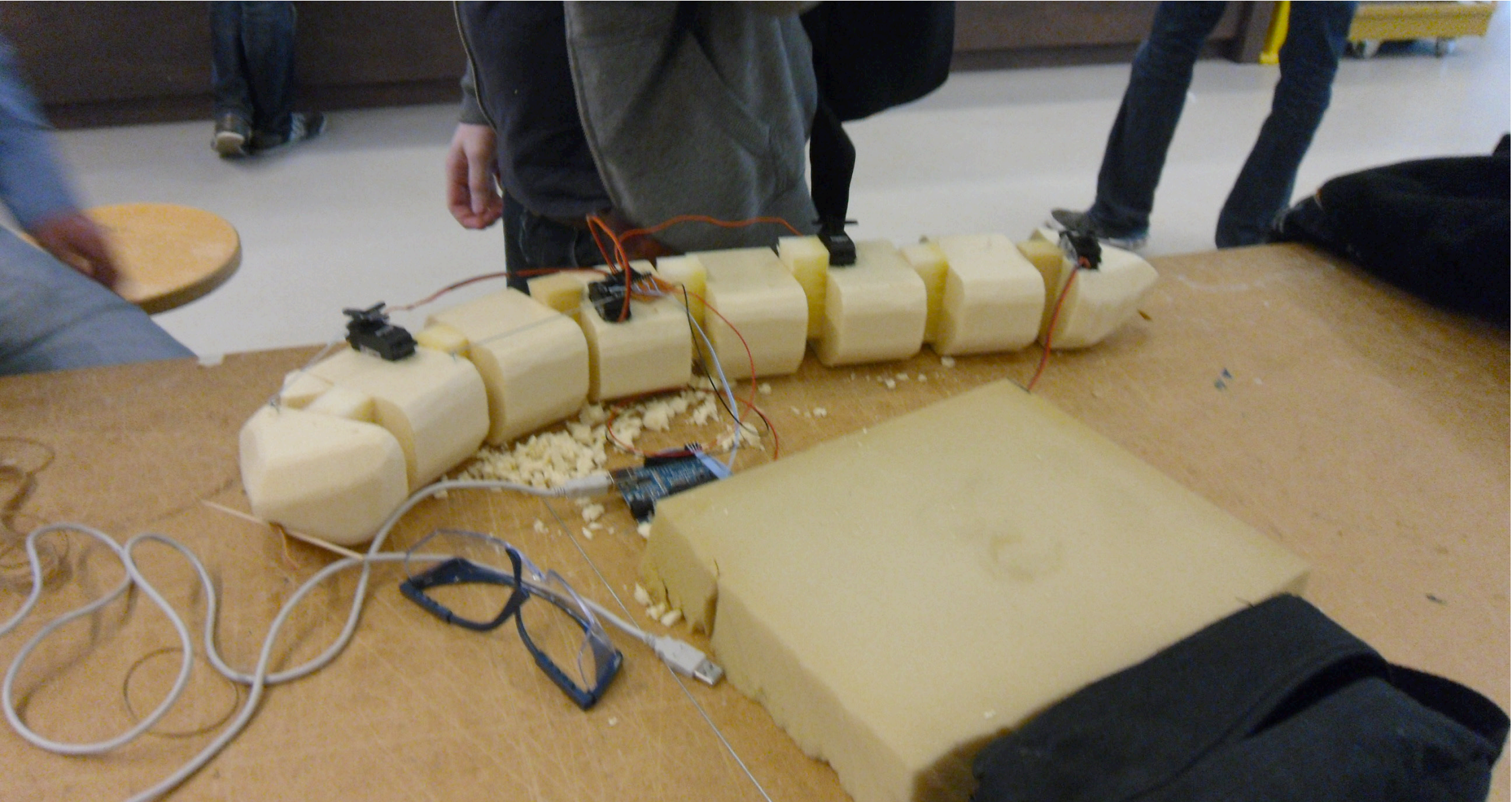
To guide this collaboration, weekly meetings were held with Etienne Gernez who is a member of the core Protei team. This core team consists of individuals who are actively involved within the Protei project. In the summer of 2011 this team was invited by Piem Wirtz of V2 to come to Rotterdam and work on a big prototype. This team included Cesar Harada who is the initiator of the Protei project.





Exploration

To kick of the project a pressure cooker was done to explore the context of the project. By going through the design process within two days it was possible for the teams to get some first ideas and insights about the project.



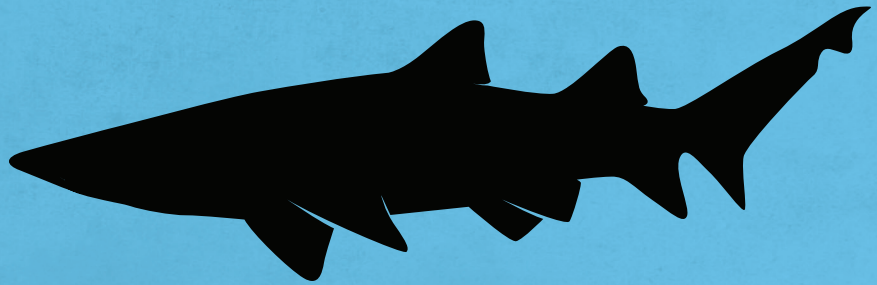
Exploration Pressure Cooker & Stakeholders

The first day was mainly spent on meeting the client: Piem Wirtz. She works for V2 which is a center for art and media technology in Rotterdam. They organize presentations, exhibitions and workshops but also do R&D within the field of art. In this meeting Piem provided the teams with a briefing that gave more insight into our expected involvement within the Protei community. The main contact point for the teams would be Etienne Gernez, a member of the core Protei group. As students of the University of Technology Eindhoven we were expected to work on the shape shifting hull of the Protei boats (drones). The shape shifting hull prevents the oil boom from starting to function as a rudder. This aspect of the design was still quite new and could use some new innovative improvements.

On the second day of the pressure cooker work was done on two prototypes. These prototypes were made to test the possibilities of altering/improving the shape shifting hull. A snake like prototype was made to experiment with this type of movability. The second prototype relied on a movable hull that is equipped with three keels. By turning the front part of the hull a keel with a different angle enters the water and the boat will head in another direction.

These prototypes provided the teams with new insights in how to improve the movable hull of the Protei drones. Some experience was also gained in the making of sailing boats; it turned out to be quite a challenge to build one that would actually float.

The exploration was followed by a phase that was marked by a lot of different meetings. In these meetings all the stakeholders discussed their needs and expectations. The stakeholders included: Etienne Gernez (main contact point), Next Nature coaches and the students of the Wild Robots project. Ideas and goals were changed a lot by the teams because communications between all the stakeholders was not always optimal.



Design Brief

Because of this the explorative phase of the project was marked by a lot of change in ideas, interests, goals and project vision. Individual design briefs were written to provide insight in the vision on the project and the goals that would have to be achieved.

Project Vision Species

A project vision was developed to help structure and clarify the goals and activities of this semester. This project vision was created by the members of group 1. This vision was realised during discussions on how to proceed with the project. The outcome of these discussions was the idea of approaching the Protei drones as a new species.

Protei has as a goal to create a vessel that can “live” autonomously and that can perform tasks as a swarm. In this description, similarities with the properties of a species are pointed out below. The team decided to approach activities within the Protei project as if they were designing a new species. This vision provided the team with a clear framework to identify design opportunities and set goals. By doing some research the team found out about a short list of attributes that each species has. The attributes that have a connection to the development of Protei drones are listed below.

- Evolve -
As many species Protei will evolve over time. This will happen through development of the Protei concept by the open source community. Each prototype iteration might add to the evolution of the Protei species.
Design opportunity: create an evolution road map

- Reproduce -
A new Protei will be born through the open source community. Interested “parents” can download plans or buy a kit with which they can build their own Protei. To ensure compatibility between different “breeds” of Protei, a certain standard will need to be set.
Design opportunities: development of a Protei building kit, development of open source community (a clear communication channel) including standards.

- Respond to stimuli -
A Protei responds to its environment. For example to cope with different wind directions when sailing, to objects blocking its path and to other Protei with which it is hunting for oil.
Design opportunities: What sensors should Protei have? Designing behavioral rules to which Protei should act, designing the learning algorithm inside Protei (from what should it learn and from what should it not learn?)

Project Vision Species

- Show collective behavior -
Being able to show collective behavior can have multiple advantages;
By interacting with each other Protei can share information on winds or oil spills (aka food).
With cooperation for protection, multiple Protei can, for example, stick together to protect themselves better from a storm. Together, Protei may be able to establish more efficient locomotion and quicker oil absorption.
Opportunity: Design a communication standard for communication between individual Protei.

- Live in symbiosis -
Protei could also be able to live in symbiosis with other organisms. In this case Protei will for example help birds who are covered in oil. While this is a rather extreme example, it might be more realistic to have Protei co-evolve. This can happen between different species of Protei by delivering software updates to each other. But maybe also between Protei and animal species.

Project Vision Design Brief

This species framework was the base of the personal design briefs of each team member. With this framework in mind activities and goals were defined and design opportunities were chosen. A summation of the goals, activities and opportunities are found below.

- Design Brief Roel -

At the midterm presentations I want to present my research and my first ideas of group behavior. In the presentation I will show a visual of the environment in which the drones will be placed. This visual will include all the important aspects of the ecology. It displays the flora of the region, the fauna and also the influence of humans in the environment. The research I did on swarm behavior will be summarized and presented. The main point I will hope to receive feedback on is my ideas for swarm behavior. So this will be the key part of the presentation.

For the final exhibition I want to make a visual model that accurately displays a Protei swarm cleaning up oil spills. In the most ideal situation I will also have a small scale physical swarm that can execute swarm behavior on a small scale. Using the data a gathered about the swarms and the environment I will make a design for the drones.

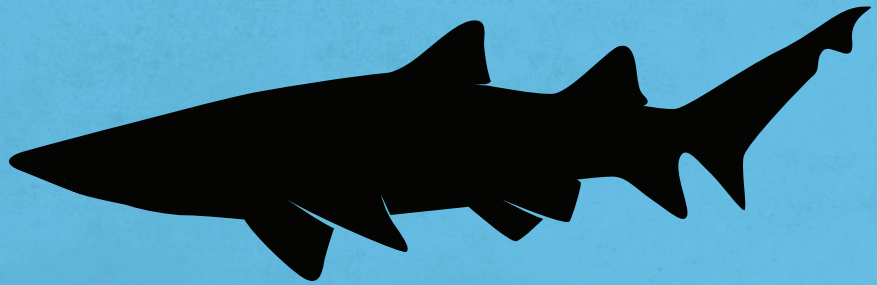
This design will be based on the tasks that the drone has to accomplish, the environment and the swarm behavior. It will not be restricted by current technology or feasibility.

- Design Brief Paul -

My personal direction for this project is to get an understanding of how the boats communicate with each other. Growing up on a farm, I've always been around animals and I want to research their communication and integrate it in the communication of Protei. By looking at how animals communicate with each other to hunt or to prevent from being hunted upon, I want to create a 'language' for the Proteii that is stripped down to its essentials. They should only communicate if they have to, so there should be as few rules as possible to 'hunt down' the oil-spills.

For the final exhibition the goal is to combine everyone's efforts into a complete functioning Protei species.

These design briefs had some similarities. Because of this the decision was made to team up and work out our next steps within the project.



Research

A research phase was initiated to get better insight in the contexts of the design opportunities. To structure the research three subjects were defined. The subjects of the research were: environment, swarm behavior and animal hunting patterns.

Research Environment & Swarm Behavior

- Env
Research was done into the environment in which the Protei species will be placed. The focus of this research was the Gulf of Mexico. The reason to investigate the Gulf was that it was the scene of the largest oil spill in human history. Another interesting aspect was that the environment will have influence on the development of the designed Protei species.

- Conclusion -
The research that was done concludes that multiple things will have interactions with the Protei species. For example the weather will be of importance because the Gulf area is known for currents. If possible Protei must anticipate these currents and react appropriately. Secondly, Protei will have to deal with a lot of mammals and big fish that come to breathe or feed at the surface. These interactions can be taken into account in the design of the Protei species. The Gulf of Mexico's north shore area is filled with oil platforms. Protei will have to avoid these platforms to keep on the right track. Finally the Gulf of Mexico is intensively used for fishing and recreational activities. Just like the oil platforms, Protei will have to make sure it does not run into these other boats.

- Swarm Behavior -
Protei will eventually operate as a swarm of robots. For this swarm to work and communicate efficiently there will have to be a form of swarm behavior. This research will be used to get inspiration and steer the process of designing the Protei species' behavior.

- Conclusion -
By looking into already existing swarm prototypes the team got a lot of inspiration. One prototype video named
"Invading Robots" was particularly interesting.

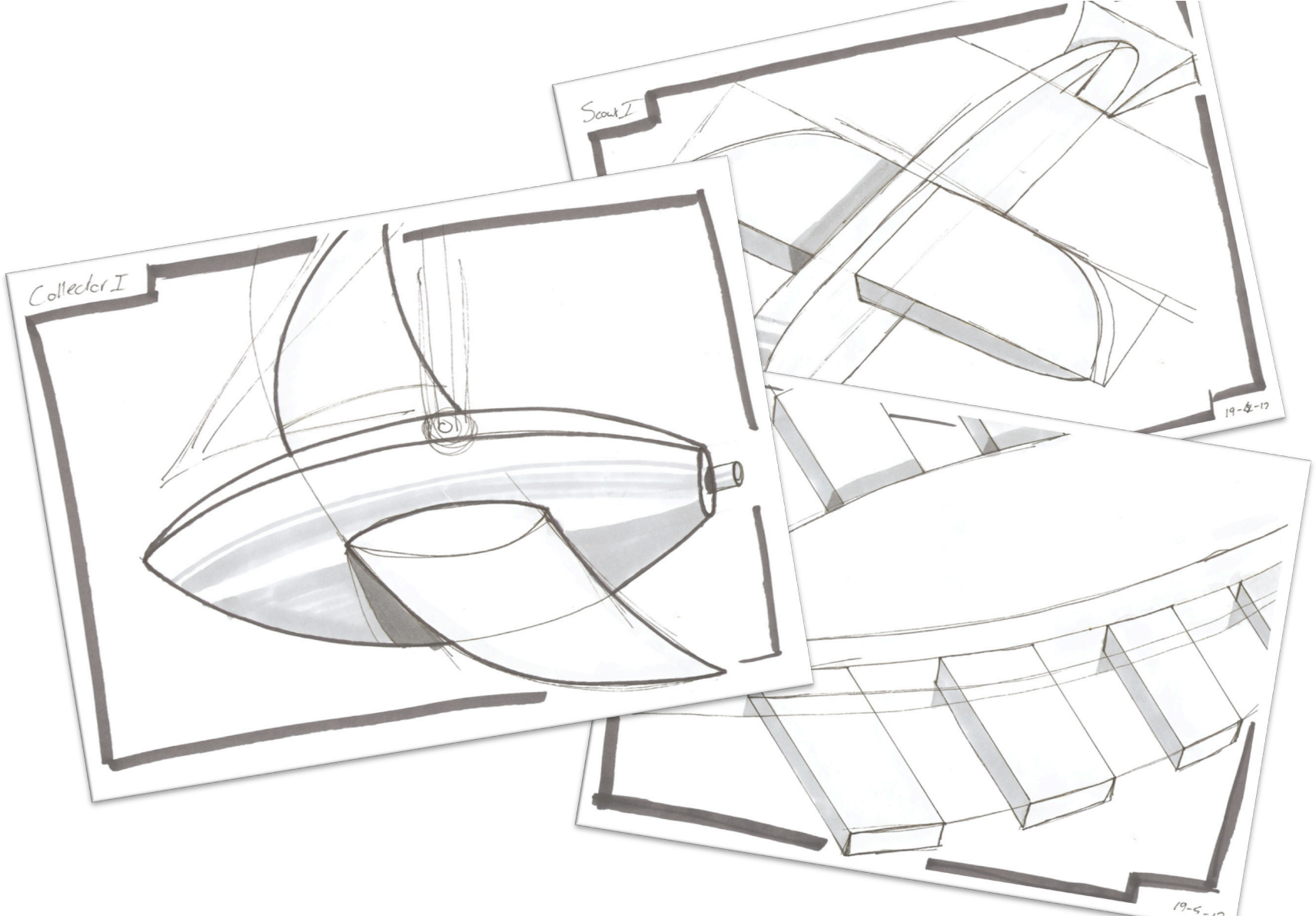
The robots in this video cooperate to "steal" a book from the shelf. The cooperation is based on roles. Each robot has its own role and executes the tasks that are linked to these roles. Firstly there is a scouting robot that explores the area. Secondly, a flying robot navigates through the area and attaches itself to the ceiling. From this vantage point it starts to search for books. When it has found one, the third class of robots maps out a route to the bookshelf. A fourth kind of robot that has grasping arms will be transported to the site of the book by the fifth and final class of robots. Here the grasping robot will climb to the bookshelf and retrieve the book.

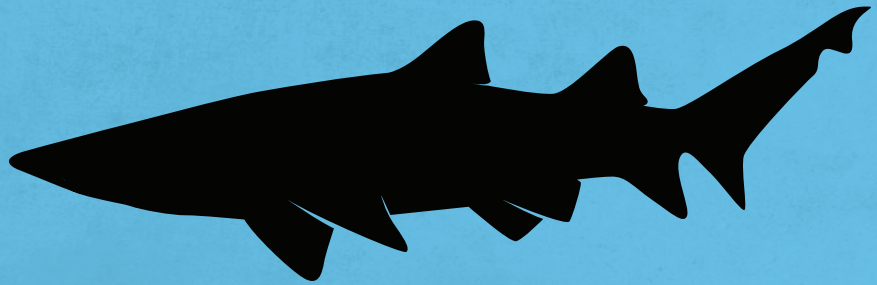
RESEARCH ANIMAL HUNTING PATTERNS

- Animal Hunting Patterns -
Because Protei will be “hunting” for oil it was interesting to learn more about animal hunting patterns. This research will be used as inspiration during the ideation phase in which we have to design the Protei species’ behavior and “hunting patterns”

Conclusion
The most interesting thing that was learned from this research was that there are animal groups that consist of different roles and tasks per animal. While at the same time there are swarms where every individual has the same task, like shoals of fish. The fish have such a smooth movement that it appears to be one big creature, where in fact there are often hundreds of fish in a shoal. This is done by only following a few simple rules and by doing this they have a much higher change of survival when they are attacked.

Animals hunt in groups in order to get more food. As a group they are able to track down larger and more prey than if they would hunt individually. The same thing can be said if the Protei drones would work together. For example if they would work in a group, they can prevent the oil from drifting away by surrounding it, while others are cleaning the oil spill. This way the spill will be cleaned as quickly as possible.


Collector I
Scout I



Ideation

The ideation phase was started with the obtained knowledge about the division of roles, the creation of classes and the tasks each class carries out. In this phase the team brainstormed, created a NetLogo model and had an expert meeting at Imtech Rotterdam.

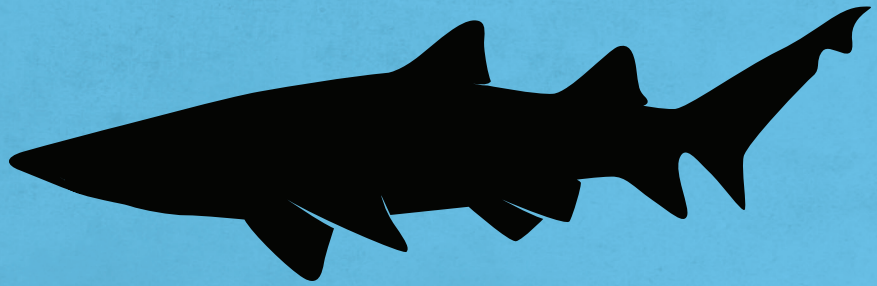
Ideation Brainstorm & NetLogo Model

The research had interested us to create a system of classes ourselves. This idea came forth from the video we saw of the “Invading Robots” prototype. This was also represented in the hunting tactics of some animal species. This combination of technology and nature fitted the team’s vision of a Protei species. The main focus of the ideation would be a class system that involves multiple roles with specific tasks. This decision was also supported by the need for a more specific operation plan. The team felt that the current framework of just oil collecting drones would not suffice.

Brainstorm sessions and discussion brought forth the final idea of having three separate classes. Firstly a scout class that will detect and monitor the oil spills. The second class is the collectors. These collectors are the original Protei drones that collect the oil. Finally the HQ class is the heart of the oil collecting operation. The HQ is a boat that will (still) be manned.

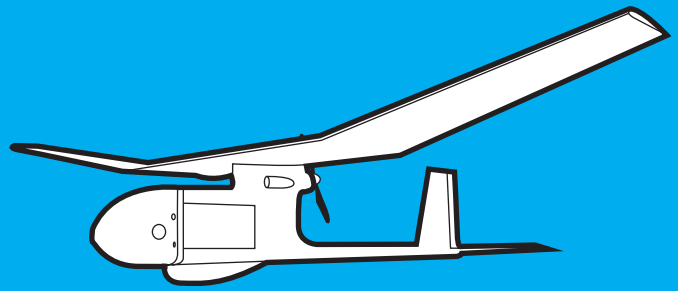
A NetLogo model was created to explore the scout class. In this model the scouts identify the oil. When the scout vessels are in a patch with oil they stop and the collectors start to move around and collect oil. With this model we noticed that the scouts will not be able to anticipate the movement of the oil. If the oil spill moves the scout can no longer sense it. In this case it will have to start searching for it again.


Imtech
Marine
& Offshore



IMTECH

From the results of this model the team concluded that this application of the scout class would not be optimal. Improvements would have to be made. The team presented its ideas at Imtech. Points of improvement were pointed out in the feedback of and the discussion with two employees at Imtech.

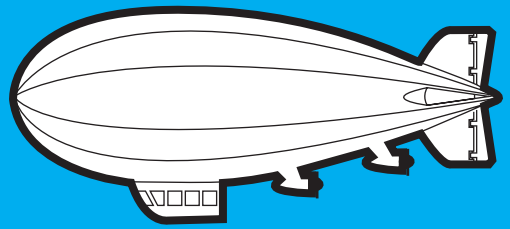


Pros

- Fast
- Stable
- Already in use
- Proven tech

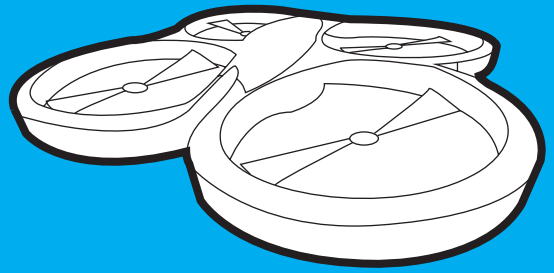
Cons

- Short flight time



- Energy efficient
- Long flight time

- Slow
- Unstable



- Stable
- Easy to build
- Already in use

- Slow
- Very short flight time

IMTECH EXPERT MEETING

Via Piem Wirtz an expert meeting was arranged with Imtech Rotterdam. Imtech is a technical service provider in the field of electronics, ICT and mechanical engineering. Piem had shown some of the teams work to Mart Hurkmans, the coordinator for research and development at Imtech. Imtech initiated work on a project about autonomous boats and wanted to have a meeting with us to discuss the progress and provide some expert insight on ideas and expectations the students of 'wild robots' had.

After introducing Mart to Protei, the team discussed their idea to work with multiple roles for the oil collection. It was mutually agreed that a scout role would not be very efficient if it was located in the ocean. Currents are continually changing because of water profiles within oceans and especially places like the Gulf of Mexico. These profiles would make it nearly impossible for a boat based scout class to accurately anticipate the oil spill movements, the sense radius would simply be too small for that. One of the employees mentioned the possibility of an aerial scout. Such a scout has two advantages. It has a good overview of the operation and it can detect/identify oil quite easily from above because of its color. This showed similarities with the "invading robots" video that was included in the research.

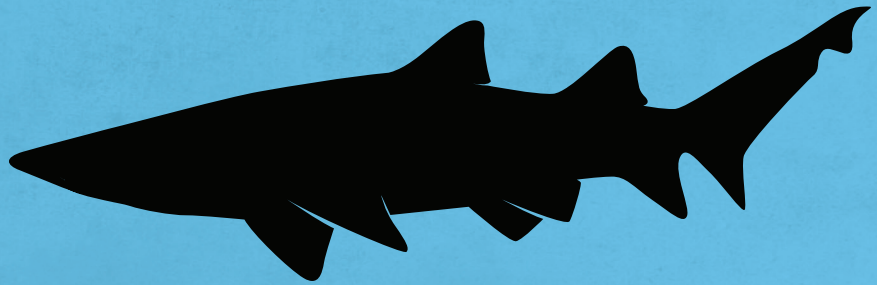
The idea of the Headquarters was briefly discussed. They liked the concept, but could not provide us with information on this subject. Because this is something that Imtech is also still exploring with a semi-autonomous system. In the future they would like to create a fully autonomous one.

The activities in the ideation phase, especially the expert meeting at Imtech, supported the presented ideas. Because of this the ideas were developed into a concept.

The idea of having an aerial drone sticked with the team.
A short research phase was initiated to find out what kind of aerial drone would be the best.

The visual that is shown to the left shows the outcome of the research.


Protei



Concept

There are birds cleaning the teeth of hippos. Fish that do not want to swim themselves, but instead travel along with a larger fish. However what was even more interesting is that within one specific species, like ants, they operate in a hierarchy. A similar hierarchy forms the basis of our concept.

Concept Approach

An ant colony consists of a queen who's most important task it is to produce offspring, worker ants who care for the queen, the young ants and the nest. Finally soldier ants protect the colony from enemy ants and other insects. Over the years they have evolved so that they have become specialized in their specific tasks. And because they are specifically build for their tasks, they can fulfill them more efficiently. If this hierarchy happens in nature, it should also be applicable to the concept.

By specializing the Protei species can also fulfill their tasks more efficiently. However creating three different roles within the same species will create another benefit for the Protei. In the animal kingdom there is no such thing as money, but when a species needs to be built from the ground up, this plays an important part. By using different roles, not every single vessel has to be equipped with every sensor and that will cut down the costs.

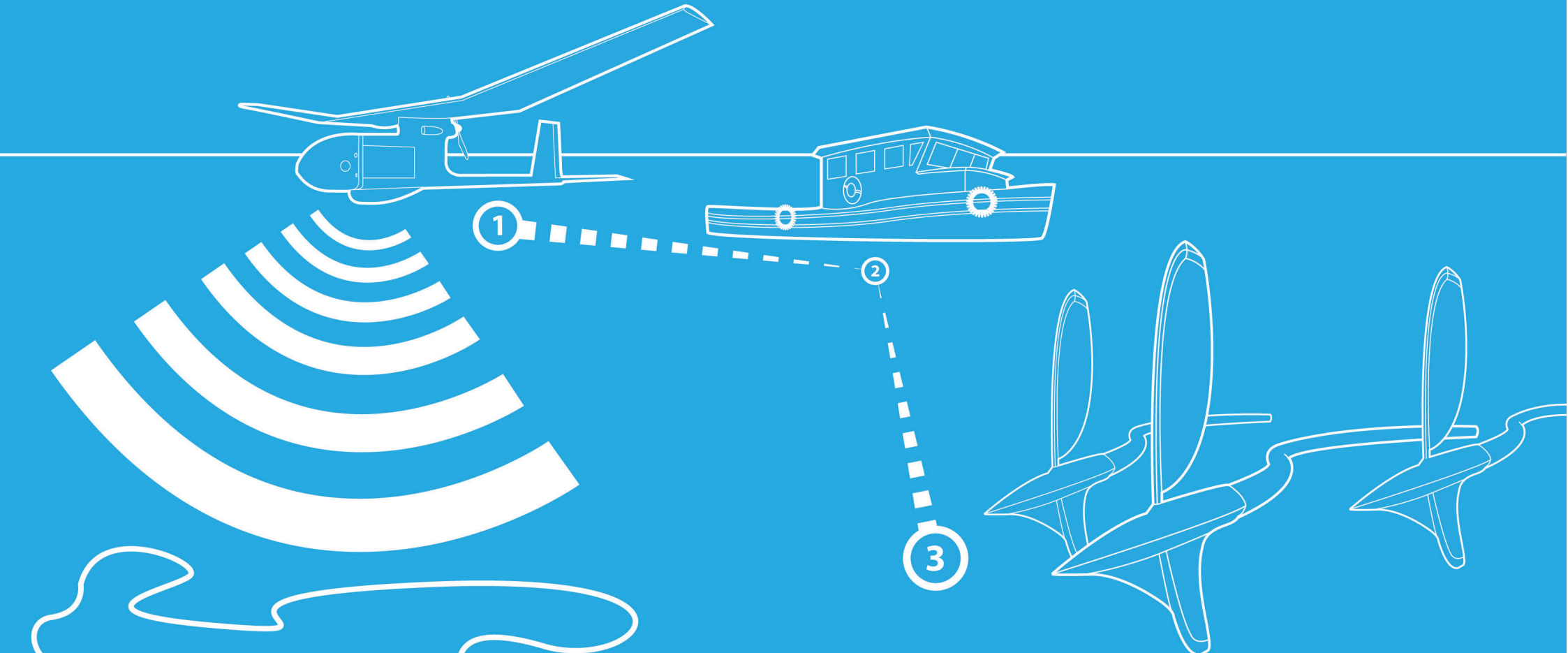
After brainstorming about how multiple roles could be improved, the decision was made to work out a short term feasible hierarchy. This is in contrast with Protei's ambitious plan to become fully autonomous.

That's why the team decided that human interaction will still be needed for example repair the broken vessels quickly, so they can begin with the oil-cleaning operation again. One class will be devoted to collect the oil. While the scout class will have an aerial application connected to it.

1: Scan

2: Command

3: Collect



Concept Classes & Tasks

A description was made of the main tasks. Every single role is explained by using verbs. An overview can be found on this page

- Scout (UAV plane) -

- Identify: The scouts should be able to make distinctions between different types of oil. To achieve this, the scout is equipped with a camera. With color identification they are able to identify and monitor the oil which the collectors will have to clean up.
- Communicate: The data that is collected will be sent to the HQ.

- Collectors (Protei boats) -

- React: The collectors have to react to the input that they are given. When the HQ gives those data on where to go they follow these instructions.
- Move: With the directions of the HQ, the collectors are able to sail autonomously to the location of the oil spill.
- Transport:The collectors will notice when they have collected their maximum amount of oil. In this case they will have to navigate back to the HQ.
- Sense: The collector is able to sense oil. When it exits an oil spill it has to make sure it is cleaned entirely. By doing another run it can sense if all the oil has been cleaned.

- Cooperate: Within a collector group each vessel has to cooperate and make sure the group works efficiently by not bumping into each other and staying in formation.

- HQ (Manned vessel) -

- Monitor: The humans who operate the HQ have to monitor the development and progress of the oil skimming operation.
- Forecast: The personnel will process the data that is coming in from the scout drones. By observing ocean profiles and weather forecasts the personnel can predict were the oil will be moving.
- Coordinate: HQ personnel has to be able to use this data and coordinate the operation by sending commands to specific vessels.
- Repair: As the collectors come back to HQ they have to be emptied and controlled for malfunctions. These malfunctions will have to be repaired. Units that are “missing in action” or heavily damaged will have to be replaced.
- Store: The oil that is collected from the collector vessels will have to be stored and prepared for shipment to shore.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THE
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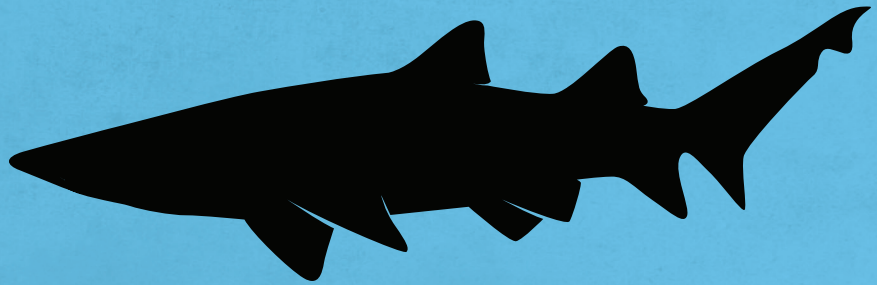
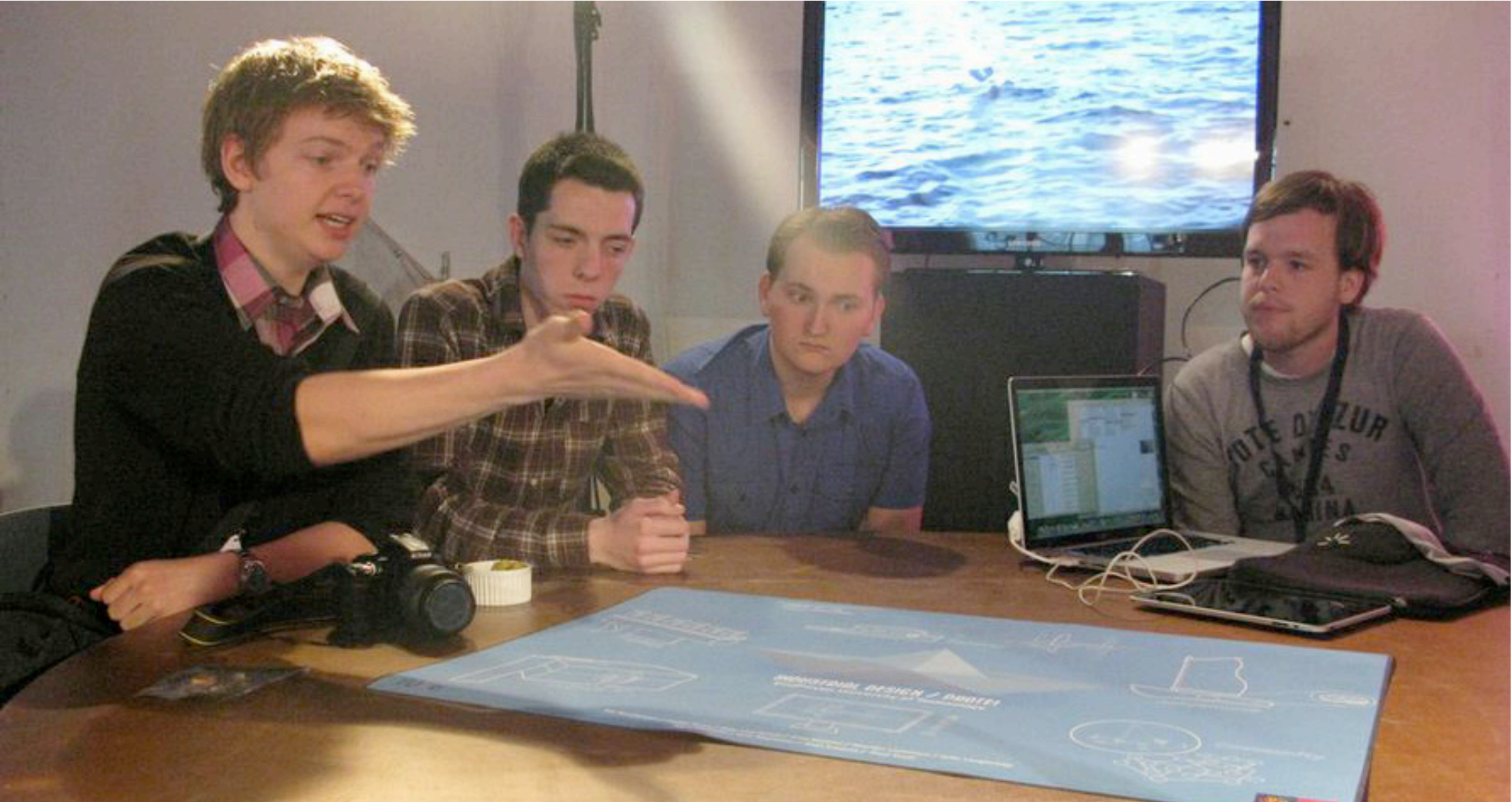


D.E.A.F Festival

In May, near the end of the project, the opportunity arose for the "wild robots" projects to present at D.E.A.F the Dutch Electronic Arts Festival in Rotterdam. On this festival many different projects were exhibited, but the most interesting one was Protei.



D.E.A.F.

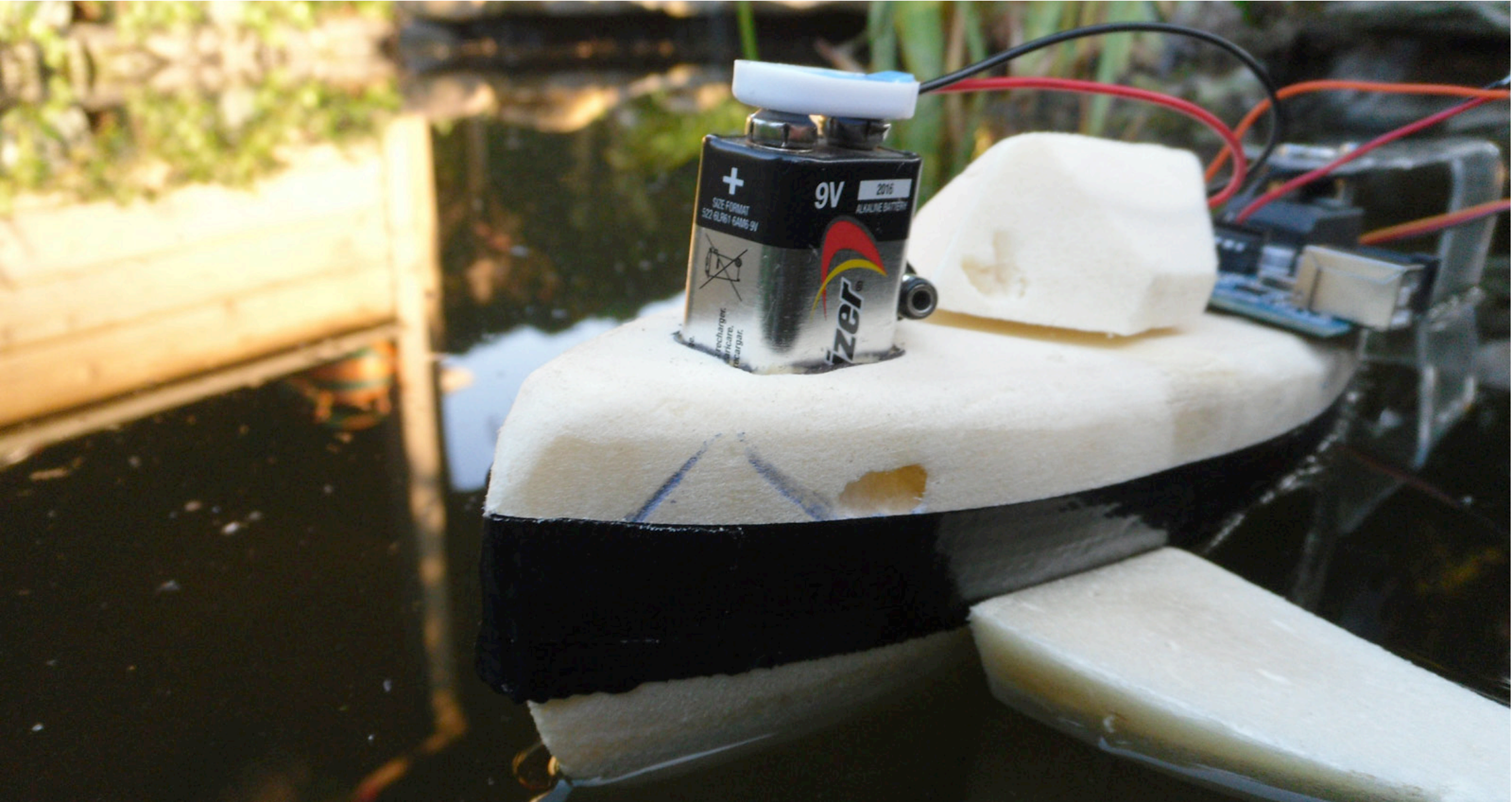
Protei brought their sixth iteration to Rotterdam, a six meter long sailing drone. To back up their presentation an informal exhibition was scheduled where the teams could present their work. In four sessions of fifteen minutes prototypes, a video and posters were exhibited. All four sessions were spent discussing the projects with the founder of Protei, Cesar Harada. He was very interested in the many different directions of all the projects and discussion was quite elaborate for every concept.

The hierarchy concept was presented to Cesar. Reactions were based upon the experiences the Protei group had built up over the years. This feedback fitted quite nicely into the vision of Protei as a species.
Energy consumption was discussed and we agreed upon keeping it as low as possible. Of course this is always the case, but if you are in the middle of the ocean it is even harder to replace the battery if it has run out of power. This also creates even more waste in the world's oceans.

The idea of energy consumption was defined as the energy a human body needs. In the body there are processes happening even though you are unconscious about, they are happening automatically. For example the beating of the heart is something that cannot be controlled; you can't pause it and let it start beating again.

But there are processes happening automatically that you can control, like breathing, this happens semiconscious. It can be stopped and started again, but actively thinking about it is not necessary. Finally there are processes that happen only because the individual takes the steps to perform the action consciously. Eating a delicious sandwich will never happen on its own and because of that input from various stimuli like seeing, smelling and touching are essential to perform these conscious actions.

To minimize the energy consumption it is important to prevent conscious processes from running all the time. In the case of the "wild robots" project it means that collectors get GPS-coordinates from the scout, the communication between the two can be stopped until the collectors have finished cleaning up the oil and have to go to the next oil spill. An unconscious process that takes place the whole time is the sensing of oil of the collector. After all when it comes across a spill that has not been found by a scout, it should be able to clean it, but if it is too big for one collector, he should be able to communicate with others to help him clean the spill.
Even though amount of audience was not entirely as expected, the team still managed to get quality feedback on the concept. Furthermore it was a great experience to be able to present our work outside of the university.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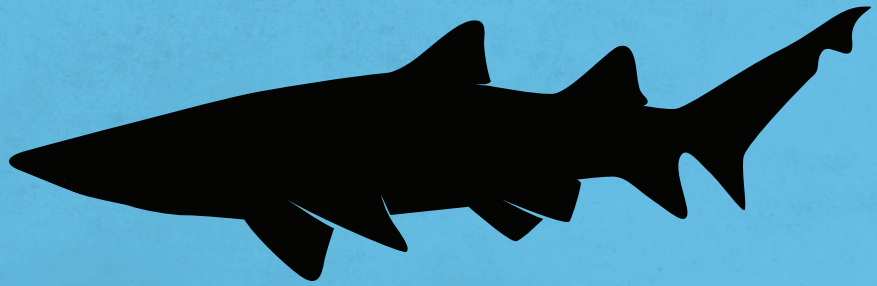
2016
ALKALINE BATTERY



Prototypes

A prototype was created to simulate the swarm behavior.
By making the concept physical, the idea of a Protei species is enhanced.

PROTOTYPE V2

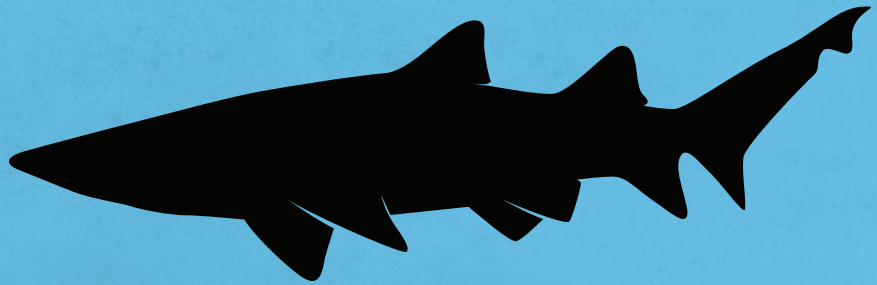
The prototype (V1) that is show on the title page functioned as an exploration. With this prototype the team validated the possibility of using a tail flipper as propulsion.

For our prototype the aim was to simulate what would happen on the ocean when an oil spill was detected. In this case the most important keywords that were worked on for the prototype were ‘observe’, ‘monitor’ and ‘react’. These verbs are connected to the three different members of the Protei species in the specific order scout, HQ and collector. The most important aspect with this setup is to build the communication between the three roles.

To establish the communication between the HQ and the scout there was chosen for a combination of the Arduino and Processing software. In the scenario described before, the oil spill was already recognized by the scout, so the scout did not have to move to a specific location anymore, that is why we chose to instead of building a UAV (unmanned aerial vehicle), we used a stationary webcam to perform the role of the scout. In the actual sea it is much harder to detect oil, then you would have to keep in mind that the color is not always black; the color is altered by currents, humidity, quantity of light and oil thickness. In that case you would need an infrared camera to observe the oil, but in our case we chose for a normal (web) camera.

This camera is connected to the computer or in other words the HQ. Because the scout is high up in the air it can get a clear picture of where the oil exactly is located and this data can be viewed on the screen. In the ‘HQ’ the employee or user is then able to interact with this data. Within the camera-feed that is displayed in Processing the user is able to draw and locate the oil. Ideally this would trigger the collectors to go hunt for the oil and clean it; however in this prototype it doesn’t work like that yet. In this case the user can control the collector from the computer by using the arrow keys to move the collector towards the oil spill. With the arrow keys the user controls the servo motor that drives the ‘tail’ of the collector and he can steer this from left to right to get to the right location. This collector is equipped with a speaker. The speaker produces the sound of the Protei species. This approach was chosen because it was an interesting new way to look at the communication/behavior. It also fits nicely into the species vision. Just like animal species like, wolves and dolphins, Protei will communicate verbally.

The sound that is produced by the first collector is “heard” by another collector prototype. This prototype displays a basic swarm behavior. It will maintain a certain distance to the sound creating prototype. The behavior shown between these collectors serves as a first but final exploration into verbal swarm communication.



Financial Validation

A financial validation was made to clarify the possible financial aspects of the concept

Financial Validation

Protei started off as a non-profit organization, in which the intention is to make people enthusiastic to build their own boats to clean the oil spills on the ocean. To achieve this, several different aspects were kept in mind like driving the costs down, so that if somebody decides to join the project and build a boat he does not have to invest a lot of money in his own Protei-vessel. Because the boats are still equipped with quite a few electronics, for example, a sail control module and oil sensor, the user still needs to invest a sum of money to be a part of this project. And since it can happen that once he has set his boat in the open water he will never see it again, this may hold people back from participating. Protei should make people more enthusiastic about joining them.

Whenever a large oil spill occurs, the only one responsible for it is the oil company who owns the leaking pipe. To save the companies' image and to clean the spill they invest millions of dollars. Nowadays they use boats transformed into oil-skimming vessels to clean the oil that is on top of the water, however these are not very effective and it costs a lot of money to use them. So if for example BP is able to let other people clean the oil for them, for a sum of money of course, they would be able to clean the oil more effectively. This will save them money.

With the involvement of major oil companies as partners in the Protei project users could be rewarded according to the amount of oil their boat collects. If the user is able to control and monitor how his own boat is doing on the open ocean he can actually make some money. By participating more actively and thus collecting more oil participation is stimulated. After investing a certain amount of money, users can also earn some money. This system of rewards is also beneficial for Protei.

Recommendations

Further developmet of the concept could have included:

- Sound Design -
The sound that the prototypes make could have been specifically designed to match their identity and deployment environment. This would have added to the identity of the Protei species.

- User Involvement -

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open source community.

APPENDIX RESEARCH - HUNTING PATTERNS

Species	Key fact	Protei interpretation	Resources
Jaguars	Change prey depending on weather	Proteiishould be aware of the weather, react to it accordingly	LiveScience
	Hunt alone or in pairs/groups	Proteii should also be able to absorb oil on its own	LiveScience
African Lions	50% of hunting is done individually	Proteii should also be able to absorb oil on its own	Ecotravel
	All senses are used	Proteii should be able to sense oil (in multiple ways)	Ecotravel
	In only 10% of the kills the prey is ambushed	Ambush the oil could be an option	Ecotravel
	Stalk the prey, with one lioness leading	A leader	Ecotravel
	Team-coordination is important, especially with larger prey	Communication is essential to tackle the problem	Ecotravel
	Different techniques for different animals	Different (sized) oil-spills may require different strategies	Ecotravel
	Injured predator is helped to recover	Defective Protei is helped by others to recover	Ecotravel
Polar Bears	Eat what is available	Preference larger oil spills, also cleans smaller ones	Seaworld
	Still hunting vs. stalking	Waiting for oil on a certain location vs. moving to oil spill	Seaworld
	Stalking birth lairs	Clean oil at source first (to prevent more oil from spreading)	Seaworld
Chimpanzees	Omnivores	Also able to clean other things in the ocean	BCF
	Only hunt close to where they live	Stay in area where they are put in the water	BCF
Cheetahs	Are not very strong, but very fast	Speed is an important factor in preventing the oil from spreading	Lions.org
Wolves	Needs an average of 3 to 10 pounds meat per day to survive	What happens if Proteii haven't 'eaten' in a while?	Wolfcountry
	Oppurtunist: Will eat smaller prey if available	Can make a choice wether to go for bigger spill or clean smaller one	Wolfcountry
	Conserve energy in winter	Randomly drifting around is not useful	Wolfcountry
	Look for signs of weaknesses in prey		Wolfcountry
	Can survive without eating for a long time		Wolfcountry
	Travel upwind of wounded animal (follow his sent)	Travel upwind to capture the oil	Wolfcountry
	May travel long distances to capture prey	Is able to locate oil from miles and miles away	Wolfcountry

Appendix Research - Environment

At the moment there is a major oil spill in the Gulf of Mexico [Gulf]. This oil spill triggered the Protei project and it is only cleaned for 3% so far. Because a lot of data is available about the Gulf and the oil spill there, we will take it as our focus environment.

- What are the weather conditions in this environment?
The Gulf of Mexico has a climate that ranges from tropical to subtropical. This means that the water in the Gulf is fairly warm. Temperatures range from 18˚C in February to 32˚C in the summer.
Because of these warm water temperatures the region is ideal for hurricanes to develop. These devastating tropical cyclones strike the region nearly every year. The hurricane season officially runs from June 1 to November 30. In this time the conditions in the gulf are conducive for hurricanes to develop anywhere in the gulf. It is also possible that, hurricanes that spawned in the North Atlantic move through the gulf and pick up strength. [1]

- Is there any flora that has influence on Protei or experiences influences from Protei?
No data was found that indicates any flora within the gulf that will be of importance to the Protei species.

Is there fauna that has influence on Protei or experiences influence from Protei?
The Gulf of Mexico covers about 600,000 square miles. It is bordered by the U.S. states of Florida, Alabama, Mississippi, Louisiana and Texas, part of the Mexican coast, and Cuba. It is an important habitat for a wide variety of marine wild life.

There are 29 species of marine mammals in the Gulf, including cetaceans* and sirenians*. Cetacean species include minke, blue, fin, sperm whale, orcas, beaked whales and a number of dolphin species, including bottlenose dolphins, the saddle-backed dolphin, striped dolphin and spinner dolphin. The West Indian manatee also inhabits the Gulf. [2]

*The word cetacean describes all whales, dolphins and porpoises. All these animals have to come to the surface to breathe which means it will be likely they have an interaction with Protei.

APPENDIX RESEARCH - ENVIRONMENT

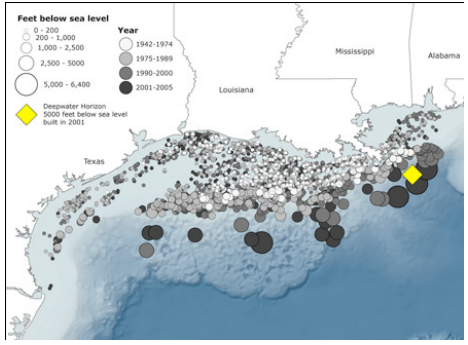
*Sirenians include manatees and dugongs, also known as sea cows. Just like cetaceans these animals breathe at the water surface

Fish species that live in the Gulf of Mexico include a number of sharks, such as the *great white shark, scalloped hammerhead, stingrays, and other fish species, some of which are sought by commercial and recreational fishermen.

* Great White Sharks spot their prey on the surface of the ocean and propel to the surface and out of the water to ambush their prey.

The gulf also habitats a wide variety of: birds, sea turtles, invertebrates and algae. But these species aren't of great influence on the Protei species.

Is there any human interference within the environment?
The Gulf is an important area for commercial and recreational fishing and wildlife watching. It is also the location of offshore drilling, supporting about 4,000 oil and natural gas platforms.
The Gulf's "Deepwater Horizon" oil spill caused the closing of fishing areas and halting of many human activities, including commercial fishing, in the area of the spill. [3]
The main thing that Protei will be dealing with is the extensive numbers of fishing and recreational boats in the area. It also has interactions with the oil platforms and the entire infrastructure that they incorporate.



Map detailing depth and locations of oil platforms in the Gulf of Mexico

Appendix Research - Environment

- Conclusion
- What are the key aspects of the environment that will have extensive interaction with the Protei species?

From the research that is done about the sub questions we can conclude that multiple things will have interactions with the Protei species. The weather will be of importance because the Gulf area is known for its hurricanes. If possible Protei might avoid these hurricanes or defend itself from them. Secondly, Protei will have to deal with a lot of mammals and big fish that come to breathe or feed at the surface. These interactions can be taken into account in the design of the Protei species. The Gulf of Mexico's north shore area is filled with oil platforms. Protei will have to avoid these platforms to keep on the right track. Finally the Gulf of Mexico is intensively used for fishing and recreational activities. Just like the oil platforms, Protei will have to make sure it does not run into these other boats.

Resources:

1. http://www.britannica.com/EBchecked/topic/379348/Gulf-of-Mexico/33257/Climate
2. http://marinelife.about.com/od/habitatprofiles/tp/GulfofMexicoMarineLife.htm
3. http://marinelife.about.com/od/habitatprofiles/p/gulfofmexicohabitat.htm
4. http://deepseanews.com/2010/06/oil-platforms-in-the-gulf-how-many-and-who-owns-them/

APPENDIX Concept Scenarios

- Processing of Collectors at HQ -
Steps
- Collectors are done cleaning oil
- Collectors check if their oil boom is sufficiently full (about 80%)
- Collectors that are full return to the HQ
- Collectors dock at the HQ
- Collectors that have not found a spot wait until there is space
- The oil booms are squeezed
- The oil is skimmed and stored
- Personnel checks the collectors for damage
- Collectors that do need repair go to the med bay
- Collectors that do not need repairs get their empty oil booms attached and leave

- Heavy Weather -
Steps
- Personnel in the HQ reports incoming heavy weather
- Collector leader receives HQ warning
- Collector leader gives order to assemble
- Collector vessels move into position
- Collectors connect to one another
- Collector leader sends message to HQ that precau tions taken

- Deployment of new Protei -
Steps
- User has created a drone and prepared it for deploy ment
- Drone scans for nearby HQs
- Drone checks if HQs are in need of a drone of its own class
- Drone moves towards HQ that is in need of its service the most
- When in range the drone gets its orders from the HQ personnel

Appendix Concept Scenario

- Scenario Cleaning an oil spill from beginning to end -
The headquarter has just arrived in the Gulf, along with a couple of scouts and dozens of collectors. Only just after they arrived there the headquarter gets information about an oil spill that just happened only a few kilometers away. He gets vital information about the oil spill, like location and size, but it also gets information about where the oil will go next. To get a better idea of where the oil exactly is a few scouts will be sent out into the air. These scouts are equipped with a camera that's facing the sea. After the scout has made its way to the oil spill, he will hover over it and sent the collected data to the collectors that are on board of the headquarter. The collectors will then be released into the sea.

Because they know exactly where the oil is, they can easily find their way towards it. While the collectors are cleaning the oil with their oil absorbent tails the scouts keep monitoring the position of the oil. They will only return to the HQ if they run out of energy, or if the weather is too harsh to stay in the air (storm, thunder). The collectors however are able to stay in the sea as long as it is needed. They will split into groups to attack the oil from different sides. If one group is finished cleaning their part of the oil, they are smart enough to make a decision on which group to join next.

Variables that are taken into account are: Distance towards the other group and time remaining to clean that part of the oil spill. When the groups of collectors are done cleaning the oil spill and the scouts do not obtain any oil in the area anymore, both will go back to the HQ where the oil will be squeezed from the collectors' tails and/or repaired. The HQ will then go to the next oil spill, or if there isn't one where there is already another HQ, it will stay in position, waiting for more oil to clean.