Project Final Report	Multi Environment Air Cushion Oil Spill Fast Response & Post Emergency Remediation System SST.2008.1.2.1-234209	COOPERATION Project funded by the European Commission Seventh Framework Programme (2007 -2013)

PROJECT FINAL REPORT

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Name, title and organisation of the scientific representative of the project's coordinator:

Coordinator: Dr. Federica Marotti, INNOVA SpA, Italy

Tel: +390640040358

Fax: +390640040364

E-mail: f.marotti@innova-eu.net

Project website address: http://www.hoverspill.eu/

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Executive summary

The Hoverspill project is a milestone in the development of solutions for oil spill response and remediation activities. The project achieved important new knowledge for technical activities and valuable know-how for commercial usage. Hoverspill ACV (Air cushion Vehicle) and the oil-water separator (Turbylec) that were designed and realized is the result of 42 months of R&D based on the outstanding, plus the experience of the partners in more than 20 years of activity in building hovercrafts for amphibious services and in fluid mechanics. Being the Hoverspill an innovative vehicle operating in emergency situations, an in-depth preliminary analysis was essential. This study dealt with different existing methodologies about oil spill's intervention and the possible applications of the hovercraft.

The overview on existing hovercrafts operating in this field revealed some critical issues and limits, such as the need of an intuitive piloting system in order to operate in emergency situations, the necessity of moving the vehicle in an environment with possible rocks and other objects on the water surface without dangerous consequences for the vehicle itself and the requirement of a moving and versatile platform capable of transporting and loading different devices and equipments. This was the phase where key decisions were made, therefore the idea of developing a new soft-hull, the separated lift system and a flat deck emerged from this analysis.

The technical and executive design led to the first prototype of Hoverspill where ad-hoc parts were built and provided by partners of the Consortium and other suppliers. Subsequently all the components were separately tested and problems were fixed individually before the assembling phase.

Once fully assembled, the final Hoverspill vehicle and Turbylec prototypes were tested on field to assess the compliance of the requirements defined during design phases. The feedback received by the members of the Consortium and operators were highly satisfactory.

Innovative results

Soft hull which consists of a sandwich structure composed of 2 main parts:

- an Elastic Hull said soft-skin
- a more Rigid structure

The soft-skin is hull made of foam (soft part) covered by a thin layer of polyethylene (the skin). The two parts are kept together by a system of ties that gives compactness to the structure and creates the connection between the bottom and the rigid structure.

The rigid structure is therefore a main frame which scopes is both supporting the main systems, the outfitting and the crew and creating the canalization for lift air.

MACP (Multi Air Cushion Platform) represents one of the most interesting and unexpected result of the project. Actually it represents a breakthrough in the hovercraft sector because it combines all the innovative characteristics of the soft-skin hull with the advantage of MPS (Modular Propulsion System) resulting in a very modular structure which allows MACP to be used in different context and scenarios. MACP enables the Hoverspill vehicle becoming the Swiss army knife of the environment.

UNIK driving system permits to realize curves with a very low radius of curvature. UNIK makes piloting completely different from other hovercrafts' techniques and special operations are easy to be performed.

Turbylec is a new concept of high tech second stage oil-water separator entrained by a high pressure, small size and lightweight hydraulic motor. For 20% inlet oil cut, residual hydrocarbon (HC) content at water outlet is limited to 600 ppm, which can be considered as very satisfactory for application to the Hoverspill project. These very good performances are maintained for inlet oil cut up to 25% approximately. In this range of operating conditions the separator cut diameter has been evaluated between 50 µm and 70 µm.

Description of project context and objectives

The greatest part of oil spills has a strong impact on coasts, beaches and shoals. Even if the pollution takes place at open sea, vessels often do not reach the location in a fast enough time to contain the oil spot which rapidly expands. The oil hits those areas which cannot be easily reached by traditional vehicles/vessels, nor by land nor by sea for the lack of water depth or for the muddy land. Hovercrafts (*i.e.* vehicles which lift from the solid or liquid surface through an air lubricant layer and are moved by aerial fans) are the only vehicles which can easily operate in these environments; they move easily on any liquid or solid surface, also if rough, and can operate floating or at high speed.

The existing technological solutions for the costs and the shores remediation in case of accidental oil spill consist in a system which recovers floating oils before they reach the coasts. Currently, compact dimensions vehicles, which in practice are either small vessels or pontoons with a skimmer sucking the floating oil, are the only systems which can be found on the market. Any hovercraft with appropriate characteristics for oil spill intervention and post-emergency actions is available on the market. These vehicles are capable of working in limited areas, ports, closed water areas and rarely in very shallow waters.

Then, the main driving idea of the project was the creation of an amphibious vehicle that can perform both preventive and emergency interventions on marine, coastal and land environments. Therefore the project focused on the development of an innovative integrated system (technologies and procedures) for oil spill emergencies, with immediacy and efficiency during the intervention and effectiveness during the following remediation activities.

During the progression of the project, many parameters have been taken into consideration: indeed, Hoverspill has to be able to work in different environments including areas with high and soft mud, relatively cheap and easy to maintain, capable of high operative speed (>30 kn.) and with sizeable spilled oil storage capability. Also, its size has to be such to make it quickly transportable by road, while it is also possible to station it on land or on beaches near potential oil spill dangers with no need of harbours or other special structures which are needed for traditional vessels.

Main objectives

Hoverspill represents a breakthrough both in the hovercraft field and in the oil-spill response by proposing an innovative system with high flexibility related to:

- **Autonomous amphibious performances** allowing reaching affected areas at high speed, usually over 30 knots also on land, shallow waters, beaches and also with strong contrary winds. All this without the need of ports or other infrastructure since the hovercraft can even be parked on land.
- **Easy Transport and ready intervention**. Road transport capability due to the final dimensions of the vehicle (breadth is within the 2.45m). This allows intervention in the coastal areas also in adverse weather conditions.
- **Equipment finalized to the emergency necessity and to the subsequent clean-up operations**. In Hoverspill project, a power take-off on the pulley-side of the engine permits the vehicle to

work as a power generator for all the instruments. When stationed on a beach or on muddy soft land it becomes a very effective operative platform for many types of remediation activities.

- **Floating oils separation:** turbylec is easy to install, transport and operate. It picks an oil-water emulsion from the water surface through the skimmer and it separates this emulsion in two parts, re-injecting the separated water in the environment.
- **Low environmental impact**: air cushion vehicles are particularly capable of operating in delicate locations. The footprint pressure recorded on the vehicle is very low: 1.3kPa in contrast with the human footprint of about 40kPa. This calculation permits to understand how low the influence of the vehicle on delicate grounds is. The recorded hovering height over the ground is about 20cm.
- **Easy use and manipulation in difficult areas**. These characteristics come from the use of the UNIK system of driving that permits to realize curves with a very low radius of curvature.
- **Performances and considered operative limits**. The floating reserve due to the presence and the shape of a huge volume of closed-cell foam makes the vehicle unsinkable and as stable as a pontoon in displacement. Cruise speed in water can be estimated at over 30knots in comfortable conditions.
- **Versatile structure**. The versatile structure realized by using the Softhull concept and the application of the concept of carry-over makes the vehicle easily repairable. In fact most of the mechanical components can be easily substituted, the hull and structure can be easily repaired and in case of impossibility of repairing a component, it can be temporarily substituted until the end of the mission.
- **Flat deck and Modularity**. The modularity concept applied to the flat deck permits to have a very flexible vehicle with easiness of preparing it for the following mission.
- **Diesel engine**. The project requires adapting an automotive engine for Hoverspill purposes. The choice to start from an automotive component is due to reduction in cost and takes advantage of the large diffusion of this kind of product. The possibility to easily find spare parts and at very competitive cost is the major attractive aspect of the selection of an automotive engine as the base to start for the development of a specific Hoverspill engine.
- **Comparisons with other vehicles**. Performances and dimensions appear adequate for the proposed goals, and are calibrated for the environment where it will work that is in inland waters, near the coast. The lower storage capacities are compensate by operative speed, by amphibious performances and by the bagging and floating pipe transfer system during operations in open sea. Moreover the vehicle can easily tow a boom or a tank for oil spill operations; this kind of work is very difficult with classical boats also because of the presence of submerged appendage.

The achievement of the above-mentioned objectives during Hoverspill was the result of the concerted work conducted by the partner who implemented jointly all the activities.

The Consortium carried out a deep review/survey (both from literature and from partners' experiences) in the field of oil spill response (OSR) and listed strategies and techniques potentially available from land and by sea to operate on uneasy access shorelines such as estuaries, marshes and wetland areas while focusing on constraints and limits encountered by response equipment and logistics usually used in such difficult-to-access environments (**WP1**). This review was enriched by an overview on oil behaviour and on response as well as by a global presentation of the main OSR equipment used for containing and recovering the spill. Then, a series of 16 potential OSR tasks was listed for Hoverspill in various spill response phases (pre-spill, emergency, post-spill): pollution survey & impact assessment/monitoring, oil containment, on-water oil recovery, shoreline clean-up (and assistance), spill response products application. Environmental and technical limits and constraints linked to each of these OSR tasks were evaluated. The required dedicated OSR equipment as well as the associated logistics or operational fittings to enable Hoverspill to carry out those missions were thoroughly evaluated and sized aiming at proposing a modular concept approach.

After the first reporting period, the work has moved from the more "theoretical" oriented work, to the stage where the manufacturing and testing of each of the studied components assumed a leading role in the project.

The definition of the executive design of the hovercraft architecture was defined: technical and physical characteristics of the hovercraft, such as the material, the engine characteristics (weight, size and positions in the vessel) and the skimmer design as well as the potential condition of connection and use of the several sub-components (**WP2**). After reviewing many aspects concerning the hovercrafts sources of lacerations and shocks, the Consortium elaborated the design of a new unsinkable and shockproof hull named "soft-skin", which can be easily fixed. The Hoverspill main frame/chassis was studied and assembled including the anti-vibrating system. Volumes calculations and floatability studies were performed. Honeycomb panels composing the working platform have been identified and verified.

In parallel, a high-tech oil separator (Turbylec) and its pumping system were developed and existing 1st stage skimmers were adapted to the Hoverspill environment (**WP3**). The best ergonomics for Hoverspill, which is referred and limited to the specific activities to be done, but also referred to the crew comfort and protection in relation with support and security equipments and with the movement needed spaces, was defined. In particular, the placement of the equipment and the evaluation of the space and the means needed to allow the operators working in various environments and with different equipments, were reviewed/controlled to check and verify the applicability of the systems to the new hull concept (**WP3**).

The core of the Hoverspill vehicle is represented by the MPS (Modular Propulsion System) composed by the engine, the main transmission and the propeller fan, the lift system and all the related subsystems to those connected. The definition and development of the MPS system (**WP4**) required a strong involvement of each partner who worked jointly to achieve:

- The customization of a diesel engine (derived from the automotive sector)
- MPS definition
- Definition of the thrust and lift system by means of CFD calculations
- Design of ducts and bodies
- Design of structures and supports
- Design of the hydraulic system with the power take off wedging on the front part of the engine shaft.

- Mechanical analysis of each part of the transmission: propeller, engine, pump, hydraulic circuit, hydraulic engines and lift fans.

The definition of the MPS required a constant updating during the whole duration of the project, as a consequence of the testing bottom up approach which was time consuming but reduced the failure possibilities of the full assembled system. One of these updates led to the give up with hydraulics system in advantage of a mechanical CVT system.
After the end of the design phases, all the Hoverspill components and the Turbylec separator were manufactured (**WP5**) and then tested (**WP6**). After positive testing results, the last step of the project consisted in assessing on field the performances of the ACV and of the Turbylec prototypes on the field (**WP7**) in simulated oil spill scenarios organized in the PO River (Italy) and in St-Brévin and Brest (France).

Hoverspill dissemination activity towards the research community and other relevant stakeholders was performed during the whole project and in particular during the second half of the project. A diverse mix of dissemination actions were carried out, targeting both the science community at EU and international level as well as a larger public. A dissemination article directed to a broad audience was published on the “Staying ahead of the wave. Towards greener, safer, and more competitive waterborne transportation” studies and reports (EU Transport Research - 2011). Additionally, articles on Romanian newspaper and appreciated papers and videos in local French newspapers and on their websites were published. Hoverspill took part to two international conferences with a booth dedicated to the project and participated to a joint event with the Argomarine project and interacted with the POSOW project being invited to the field trials organized as a public demonstration session of the final project meeting. The field trials organized in France were an opportunity to invite local and national authorities as well as operational bodies, industry companies and local press to assist and participate to the 2 official demonstrations. More than 50 persons attended the 2 demonstrations.

Description of the main S&T results/foregrounds

The Hoverspill vehicle is supply vessel for oil-spill fighting operations, so the ergonomics is a parameter fundamental for the project. A high grade of ergonomics has been achieved by adopting some solutions on the vehicle such as the concept of **flat deck**, the **modularity,** the **UNIK driving system** and the **not-obstructable cooling system**. The concept of flat deck and the vehicle behaviour at sea or on the ground permits the operators to move on-board with high agility and low risk for life safety. This represents a success for the project because no other ACV (air cushion vehicle) permits this high grade of ergonomics.

Particular attention has been dedicated to the so-called "devices carry-over": the majority of the elements making up the Hoverspill are easily available on the market, therefore even in case of crash or any other kind of damage, the hovercraft can be substituted or fixed quickly. Indeed, the whole vehicle's structure has been developed according to the "keep it simple" philosophy popular in the IT field. It's not just a matter of good availability of mechanical parts on the market, but also about the easiness in detecting and replacing the damaged element.

Main results achieved

Air cushion vehicle

A notable innovation is constituted by the **Softhull concept**, a solution that has been adopted in order to obtain **a system that is both unsinkable and flexible at the same time**.

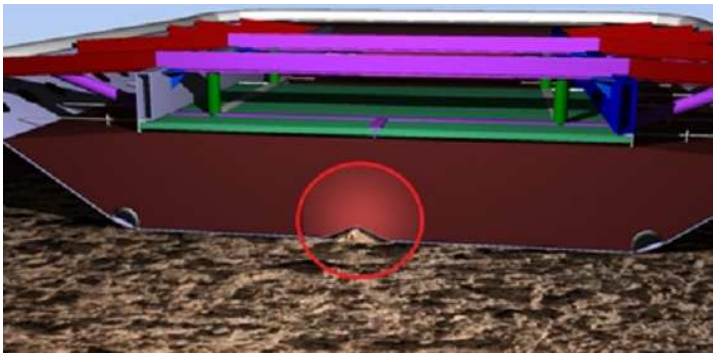


Figure 1: *The concept of elastic hull proper of soft-hull technology*

Due to the Hoverspill application, that take place mainly in environments where the chances of damages and impacts against rocks and other floating obstacles is extremely high, a standard solution such as the hull that constitutes existing hovercrafts is inappropriate because of the high costs consequent to any kind of damage. The adopted soft hull, on the other hand, reduces the risks of lacerations or breakage and even if ripped, it can be easily fixed using a portable extruder.

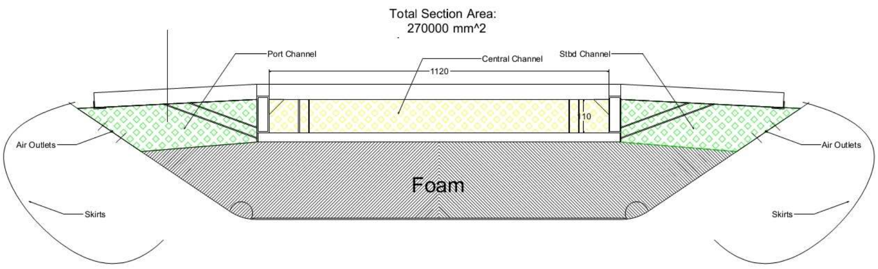


Figure 2: *The soft hull made of Polyethylene conncted to the rigid structure*

This elastic hull has been connected to a rigid part in order to gain strength for the whole structure and realize a modular flat deck, a solution that has never been adopted on hovercrafts. The presence of the flat deck permits to load different modules and/or equipments according to the requirements for the mission to be performed.

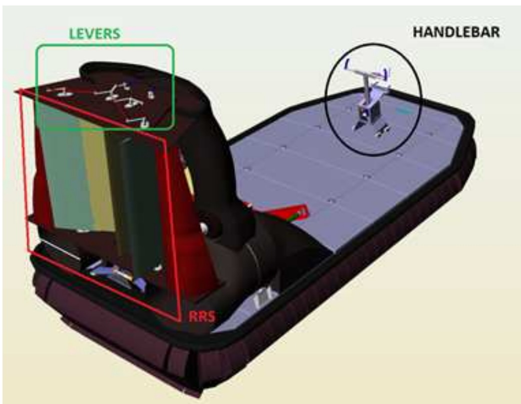
For example a hydro-cleaner is provided on-board when it is effectively needed to intervene on rocks and shores invested by an oil spill, but is not installed on-board when cleaning operations are not foreseen.

The huge range of flat deck’s possible application disclosed while progressing with the project: its versatility allowed setting up an amount of different devices that could hardly be presumable in the preliminary phase. Every need that has been detected led to a new layout: a crane has been installed on the side of the pilot seat to make it easier the load and unload operations. A retractable boardwalk simplifies boarding and disembarkation and a trunk placed beside pilot permit to store equipment and devices on board.

Since the Hoverspill has to operate in emergency situations, a specific **MPS (Modular Propulsion System) has been realized** in order to guarantee a good manoeuvrability with high propulsive efficiency and low weight. For this reason, a **diesel engine** coming from automotive sector has been adapted to marine conditions and a particular shape for the whole system has been drawn in order to minimize efficiency losses and turbulences and to avoid destructive resonances. Calibration on the engine has been necessary due to the different parameters between automotive and nautical sector for the MPS power curve.

In the MPS, a technical solution that is a peculiarity of the hovercraft is the presence of the separate lift system. The vehicle is characterized by the presence of one big aerial propeller and two smaller fans that are dedicated to the creation of the air-cushion. The main thrust system is realized by a ducted fan with a system of transmission constituted by two angular reductions and one fluid coupling that permits to isolate the torsional vibrations of the engine and of the propeller. In the project the lift system is driven by the same engine of the main propeller but its setting is studied to be separated from the main transmission. This allows the formation of the air cushion also at low-medium speed when the thrust fan isn’t effective.

The combination of all the innovative characteristics of the soft-skin hull with the advantage of MPS resulted in a very modular structure which allows the **MACP (Multi Air Cushion Platform)** to be used in different context and scenarios. MACP is a rolling chassis characterized by low production costs, on which it is possible to install different equipments (*i.e.* Hoverspill) and body works to answers to different user needs.



During the months invested in the project, the most interesting evolution we registered concerns the **control system**. Past experiences and tests conducted during the assembly of the HoverSpill demonstrated that an intuitive piloting system is essential in a vehicle that has to operate in emergency situations. These considerations led to the creation of the **UNIK system**: its peculiarity is constituted by the perfect management of those extreme

and intermediate positions essential for the reverse gear, "supercurve", and directionality when operating at low and high speed. This outcome is achieved with a double junction on the actuator that will be controlled by a single handlebar on pilot's side. Piloting is intuitive and there's a strong one-to-one correspondence between every single control positioning and the effects on the vehicle with a consequent reduced training time.
Particularly relevant has been the last period of tests when the Hoverspill operated in different areas. The first series of tests has been conducted on the Po River and it included accident simulations with functional and operative evaluations on the hovercraft. During these tests SOA and Hovertech members collaborated with CRF in order to establish the best parameters to properly calibrate the engine power curve.
Then the Hoverspill has been tested by the different partners of the Consortium in St-Brévin and Brest, France. In this case all the members of the Consortium participated and the feedback was extremely positive: both functional and operational tests were more than satisfactory and data collected allowed to pre-determine modifications to be applied on the UNIK system in order to reach the optimal solution in terms of ergonomics, manoeuvrability and easiness of piloting.
Ultimately, the resultant hovercraft is a real breakthrough in the field of oil spill emergency intervention and it can be considered as the outcome of more than 20 years of partners experience and experiments. Furthermore, the scalability of the Hoverspill is excellent because of the reduced costs and the high availability of parts on the market: this characteristic portend a huge forward step in environmental protection.
The summarization of the technical project results are here reported:

Hoverspill Results:

Hoverspill is ahovercraft with separated lift system and finger skirts, it's main characteristic is the Flat Deck

Length L	**5,5**	**m**		
Breadth B	**2,45**	**m**		
Height H	**2,31**	**m**		
Main Deck Height D	**0,45**	**m**		
Height while on cushion h	**0,25**	**m**		
Maximum Weight	**1600**	**kg**		
Payload	**650**	**kg**		
Autonomy (standard tank 120 lt)	**10**	**h**	**8h**	**Working**
				High speed transfer
			2h	**6 h at cruising speed (32/35 kn)**
Performances: Maximum speed recorded	**30**	**kn**		
Wind: Recorded during tests	**25**	**kn**		
Maximum Wave height recorded during tests	**0,7**	**m**		
Reverse motion	**New Integrated system realized**			
Heavy duty and Work ability				
Driving Easiness	**New "Unik" command**			
New "Softhull" Structure: Flexible Hull, Foam, Main frame, panels and grids				
High Capacity to withstand high speed impacts and parking on rocks due to the application of Softhull system				
Unsinkability	**1630**	**kg**		**Buoyancy**

Additional Results

Concept of Carryover applied to most of the components		
Cargo space permitting heavy duty and Work ability	3,5 x 2	m^2
Maximum light weight	900	kg
Installed power	130	kW
Min Power available for the propulsion	95	kW
Ducted Propeller Diameter	1300	mm
Propeller thrust	>2500	N
Max Power available for lift system	35	kW
Lift flow rate	7	m^3/s
Lift flow rate appropriate to the operational situation (adjustable flow)		
Capacity to work at low speed		
Capacity to work at low and medium ratio for indefinite time		
Disposition for a CS-Pto with possibility to stop the lift air or controllable pitch lift system		
Easily replaceable skirts		
Trim of the transmission system	0° - 8°	
Guidance system with integrated reversing	Driving precision	
	Capacity to stop and reverse during hover guidance	
Tank capacity	120	litres

Ability to tow a boom while keeping the drive control
Ability of trawling a boom in U configuration or in a Flag configuration for limiting the oil escaping
Tolerate driving over oil
Operate on sloping areas
Capacity to land on a muddy wet slope
Capacity to fly on a muddy land
Capacity to sustain aggressive work conditions: chemical and salt spray protections are provided
Capacity to operate in environment with seaweeds, floating vegetation and light floating debris
Capacity to fly on the oil film and to immerse in it for a long time
Remarkable marine characteristic
Floating stability
All mechanical System are explosion-proof

Figure 3: *The ACV*

Engine

The engine assembled in Hoverspill configuration is the result of the modification of an automotive engine to satisfy the Hoverspill requirements. The base automotive engine selected was the FTP 2.0 L 165 CV diesel common rail engine. The choice of a diesel engine was mainly for safety aspect due to not flammable fuel and EU standards on “not-pleasure boats”, and generally on vessels operating in the Oil spill response. The application required also high power level major than 170 CV. The base engine in automotive configuration is able to supply 165CV. With hardware and calibration modification it was possible increase power to 175 CV (continuous power) and 185 CV (temporized power) without deteriorate the automotive engine reliability, but powers above 130 kW may require adaptation at The Annex VI IMO, with considerable additional complexity. Engine structural elements analysis and experimental were performed to check that the new engine configuration had the same reliability of the automotive one. To obtain this result the automotive engine was modified. Some engine components were eliminated or tailored to satisfy new requirements. In special way the control system was deeply modified to improve safety and add function not present on automotive application. New sensors to monitoring the air filter status, the coolant heater pressure drop and the intercooler pressure drop were added. A programmable dashboard with the features of monitoring the state of the system, data logging engine parameters and display alarms condition was implemented. The engine is a subsystem of the MPS. As MPS it was studied with the peculiarity of a big modularity, also the Hoverspill engine follows this goal. All the subcomponents necessary to the working engine are installed on a specific support on the engine. The wiring was adapted to the new positioning of the ECU and other sensors and actuators. In this way it was possible to install the engine on the MPS just linking it to the engine interfaces (the electrical connection; pipeline from and to the following components: diesel tank – cooling water exchanger – intercooler; the mechanical link to the ant vibrating supports).

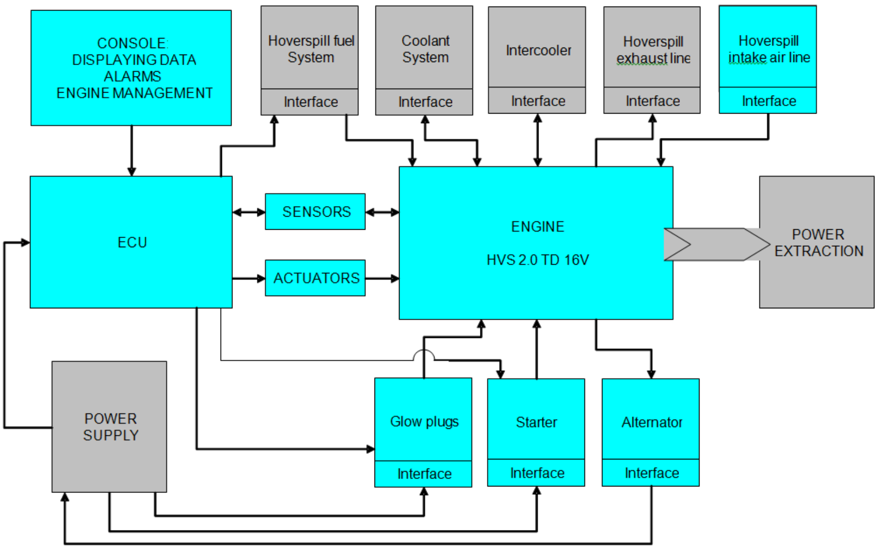
The project was developed in consecutive steps:

- The definition of the typical Hoverspill mission which will operate inside the range defined by operative limitations. The definition of the typical mission and the operative range (altitude – temperature) is reported in the table below.

OPERATIVE CONDITION	MAX CONTINUOUS POWER 129 kW	THRUST	LIFT	AUXILIARY
MOTION	90% 116 kW	0% - 85% 0 kW - 99 kW	15% 17 kW	0% 0 kW
OPERATIVE	70% 90 kW	10% - 50% 9 kW - 45 kW	15% 14 kW	35% - 75% 27 kW - 58 kW
HOOVER	60% 77 kW	0% - 10% 0 kW - 8 kW	15% 12 kW	35% 27 kW
STATIONARY	40% 52 kW	0% - 15% 0 kW - 8 kW	0% 0 kW	0% - 90% 0 kW - 46 kW

A max continuous power of 129kW was defined as adequate to completely cover the typical operative range of the Hoverspill mission. The emergency temporized power (automatically limited in time: 15s) was defined with the precise objective to manage contingency conditions, where an increase of power request is necessary to permit a safe recovery of the Hoverspill.

- The definition of a dedicated Hoverspill engine layout:

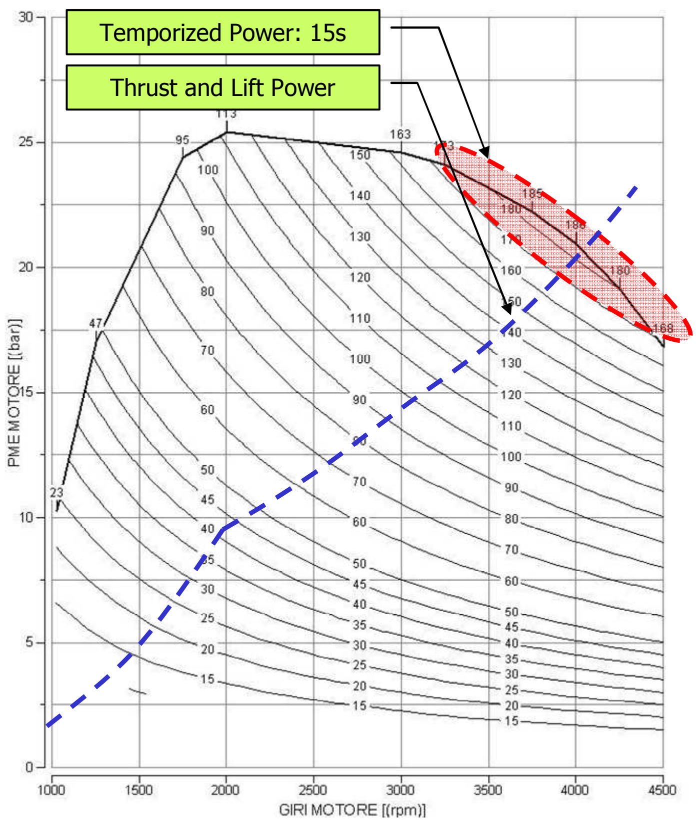


In the automotive system the engine ECU is directly connected to the others vehicle ECU. In this way the engine ECU receives and sends information about the complete vehicle system functioning. The automotive driver receives information about some engine parameters (vehicle and engine speed, temperatures, pressures, warning lamps and other). In case of failure the automotive procedure provides a general failure signal and an automatic recovery. Depending on the failure severity this recovery can produce a visual signal, a decrease in performance or an automatic engine shut off, but these recovery strategies are not suitable for the Hoverspill application. For this reason a programmable display system, based on MTA Phoenix dashboard, to give information about engine functioning was developed. This display (detailed information take from MTA Phoenix datasheet) assures a good visibility at any light condition thanks to its high contrast display and its back-lighting. This display shows 3 pages with 5 data windows with indication of page and channel name and programmable alarm light signal. The dashboard characteristics are: an integrated GPS module to monitor the Hoverspill speed, 8 high brightness warning lamps, 4 green, 2 yellow, 2 red. Each of them is needed for indicating different alarm condition. For each alarm event, the name and the value of the alarm channel are shown on display. The alarms configuration and thresholds are adjustable, direct configurable connection to sensors (active and passive), 2 CAN line that allows connecting the dashboard to the engine ECU, USB connection to communicate with a PC, high frequency data acquisition module. The acquisition system is programmable by a PC. This feature is useful to acquire anomalous engine or system behaviour. The remote analysis of the collected data permit to adjust what is wrong on the system or helps the driver to properly use the system. The warning lamps provide information about the over passing of operative limitation for the following parameter: max coolant temperature, minimum oil pressure, low environment pressure, over speed, water contamination in fuel, high pressure drop on inlet air system, high pressure drop on the coolant radiator, high pressure drop on intercooler.

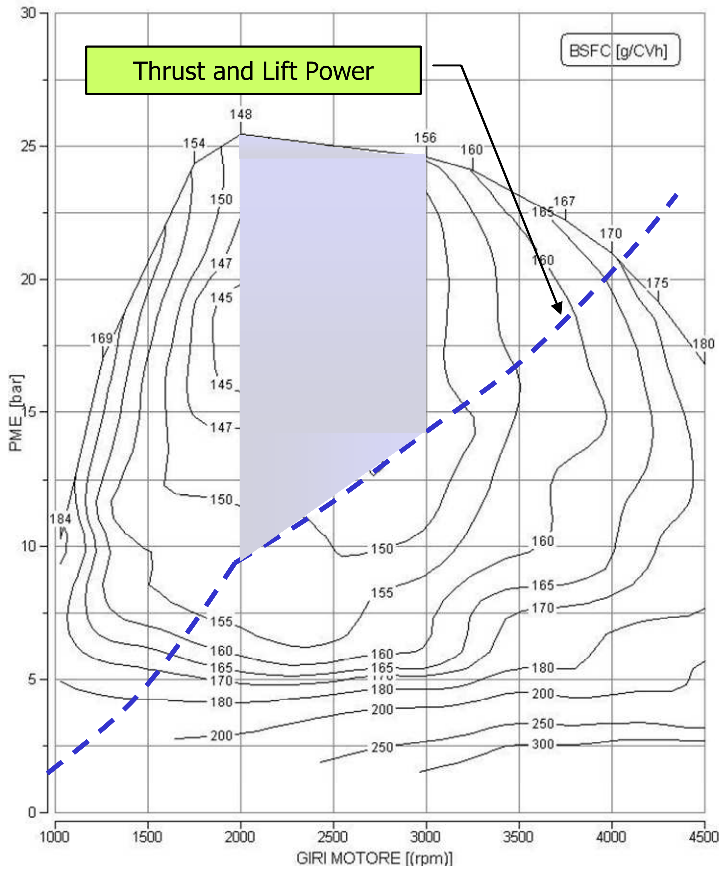
On the Hoverspill engine 3 new differential pressure sensors were implemented to better manage the following components interfaced to the engine: pressure drop on air filter line, pressure drop on coolant radiator line, pressure drop on intercooler line. The thresholds for these three parameters have been experimental detected at test bench.

The result of the application in test cell room was a specific dataset for Hoverspill application. Following the main results of the work:

Engine power supply. The picture represents the engine map about engine power distribution. The Nominal engine Power is 175CV [129kW]. For a limited time of 15s it's possible to increase the engine delivery power up to 185CV [136kW] to manage critical operations. The strategy is completely automatic. The pilot can easy select the power condition (nominal-temporized) with the Pedal level Accelerator (PLA). The nominal region is managed from 0% to 90% of PLA, the temporized region (highlighted in the picture in red)is continuously managed from 90% to 100% of PLA. The calibration was adapted to avoid instable condition during transition from temporized to nominal power. The blue dashed line represents the typical load application to the engine of propellers for thrust and lift.



Engine fuel consumption. To obtain the result described in the picture where a minimum value of 144g/CVh is highlighted, a big calibration effort was need. An accurate calibration about injection pattern, intake manifold air pressure value, rail pressure value, injection timing was developed. The trend value of specific fuel consumption is very low everywhere, but with special attention in the range 2000rpm-3000rpm, where the value is always below ~150g/CVh in the hoverspill application (the zone above the propeller thrust and lift power curve highlighted in the picture by blue shadow representation).



Turbylec

The huge amount of possible procedures that can be adopted according to the environment and the specific emergency situation cannot elude the use of the **Turbylec**. The innovative solution designed and developed by Ylec is a highly effective double stage integrated system of floating oils separation that is easy to install, transport and operate. Turbylec is the core of remediation process: it picks an oil-water emulsion from the water surface through the skimmer and it separates this emulsion in two parts, re-injecting the separated water in the environment.

The steps which brought to the innovative Turbylec started from the assumption that the secondary separator has to be compact, lightweight and easy to manipulate and clean. It has to be installed on the hovercraft and entrained with a reduced power installed. The only solution is to use rotating separators that do not exist with the above specifications. The Turbylec represents a breakthrough with respect to the state of the art having the following main innovations.

- TURBYLEC can work in a wide range of density contrast with no level control system (oil and water weirs with special blade design).
- It can be relatively simply dismantled on board.
- It integrates built in innovative rotating oil and water pumps mounted on the same axis as the separator.
- It may have no mechanical sealing (innovative hydraulic auto-adjustable sealing)
- It has a very low weight: 100 kg *vs.* about 1 ton with conventional systems for the same flow rate. This is a major point because the system must be transported by a small hovercraft.

- It is driven with hydraulic high speed motors which are compatible with the requirements of the small hovercraft power system.
- Turbylec does not need any control such as level or pressure adjustment.

The main functional characteristics of the Turbylec separators can be summarized as follows:

- Height: 1 meter
- Diameter: 380 mm
- Rotational speed: 1500 RPM
- Weight (with liquid): < 100 kg
- Maximum emulsion flow rate: 2 l/s
- Minimal emulsion flow rate: 0 l/s
- Theoretical cut diameter: 30 µm
- Range of Water-Cut (emulsion water content): 0 – 100%

The initial manufacturing solution suggested was to construct the TURBYLEC separator:

- with conventional techniques,
- assembling the rotor from multiple machined parts,
- with conventional metallic and/or plastic materials of well-known mechanical characteristics.

Then further considerations were taken into account:

- making complexities with the initial suggested solution,
- functionality of the system,
- compromise between mechanical resistance and weight of the separator

The conclusion retained is that it is preferable to manufacture the rotor of the Turbylec by rapid prototyping. The first rapid prototyping technique initially suggested by this manufacturer was stereolithography which is a layer additive rapid-prototyping process based on the use of particular resins which solidify when exposed to UV laser light. Discussions about the choice of the best material, for our application, lead to choose a somewhat different technique called Selective Laser Sintering (SLS).

The final solution enables to deliver the rotor, which is a quite complex part, in one piece only. This simplifies very much the mounting and preliminary testing. It also simplifies some issues related to sealing and mechanical adjustments. Particular attention has been given to obtain a robust and reliable conception and manufacturing of the TURBYLEC separator.

Figure 4: *manufacturing of the Turbylec separator prototype. Left: rotor – Right: complete system*

The final version of the manufactured prototype results from several modifications justified by the analysis of various test results focusing on mechanical behaviour, hydraulic performances and separation performances.

Tests of Hoverspill vehicle and Turbylec prototypes

After positive results obtained in the preliminary tests, the last technical step of the project logically consisted in assessing the Hoverspill and the Turbylec prototypes through field trials which served the dual purposes of:

- validating the feasibility for Hoverspill to achieve the presumed oil spill scenarios and tasks
- gauging the interest of potential operative users in Hoverspill as an useful support in oil spill response operations as well as in any other field of use.

The assembling and fitting of the platform lasted until the date of the tests. The week before going to France, the first on-water tests of the Hoverspill platform took place on the Po River. The following in-situ validation trials were organized in the Loire estuary and its surroundings, then in Cedre facilities at Brest.

At the time of the tests, the Hoverspill was a very new vehicle of which, of course, the good mastering and handling (behaviour, operating, manoeuvring) first needed to be acquired, that supposing inevitable fittings, modifications and repairs. Part of the time spent for tests was devoted to this crucial aspect: improvements recorded during these days were obvious and have been promising. These trials enabled to better define the advantages and also the limits and constraints of the HoverSpill. The prototype was tested on several OSR situations or scenarios simulating real polluted areas. The trials programme aimed at validating the different oil spill response protocol (*i.e.* tasks and scenarios) that were previously defined. These scenarios represented the basis for assessing both the efficiency and capacity of the Hoverspill platform, of its main subsystems and of its auxiliary devices (*i.e.* oil spill response tools) supposed to be temporarily installed on board. These trials enabled to validate or not part of the operative protocols previously defined. It was not possible to assess all the tasks supposed to be carried out but most of them were done. The simulation tests however demonstrated the feasibility of implementing in a practical and safe manner OSR tasks, as well as the interest of the modular concept.

Field trials in France were an opportunity to invite French local and national authorities as well as operational bodies (fire brigade, civil protection, etc.) and industry companies (oil, power energy) to assist and participate to 2 official demonstrations, held at the end of the trials, both in St-Brévin and in Brest.

These official demonstrations enabled to:

- wear the HoverSpill to the knowledge of operational bodies
- assess the impact of the project
- find others tasks that the Hoverspil could potentially achieve in the fields of oil spill response as well as for other civil protection issues.

More than 50 persons attended the 2 demos. Valuable technical exchange took place between the various participants leading to a global positive feedback from these demonstrations. Participants expressed their interest in the two prototypes and were looking forward to seeing the improved prototypes during a next demonstration that local authorities are willing to host again.

TURBYLEC tests

In the wake of the first test results obtained with Turbylec separator, it was decided to implement some complementary tests aiming at assessing its performances on different types of oils. These tests were carried out in the Cedre's facilities and very good performances were recorded considering the size and weight of the separator and comparatively with the performances of separators usually used.

Several types of tests of TURBYLEC prototype have been carried out to verify the general behavior of the separator. These tests include mechanical, hydraulic and separation tests.

The mechanical tests, carried out with water only, have been performed to characterize the functionning of the prototype when operating at maximum RPM and with a water flow rate of 1 l/s. Few corrective actions were required but then the prototype proved correct mechanical functioning.

The ability of the integrated water pump stage to induce pressure increase were also proven.

Some tests of the separator with water and oil were carried out with the purpose of preliminarly verifing the behaviour of the system at nominal RPM while:

- pumping water,
- pumping oil,
- separating oil and water.

The first separation tests were performed at zero water flow rate. The purpose of these tests was to verify the correct positioning of the oil – water interface inside the separation chamber while pouring pure oil at the inlet of the separator (separation chamber previously filled up with pure water). Tests with vegetal oil and gasoil enabled to conclude that the diameter of the oil weir was too small. Some modifications of the rotor were applied to solve this problem.

The separation set up tests of TURBYLEC were performed using the flow loop illustrated on Figure . These tests carried out with different types of oil (engine oil and gas oil) revealed a malfunctioning of the separator which required for some modifications of the system.

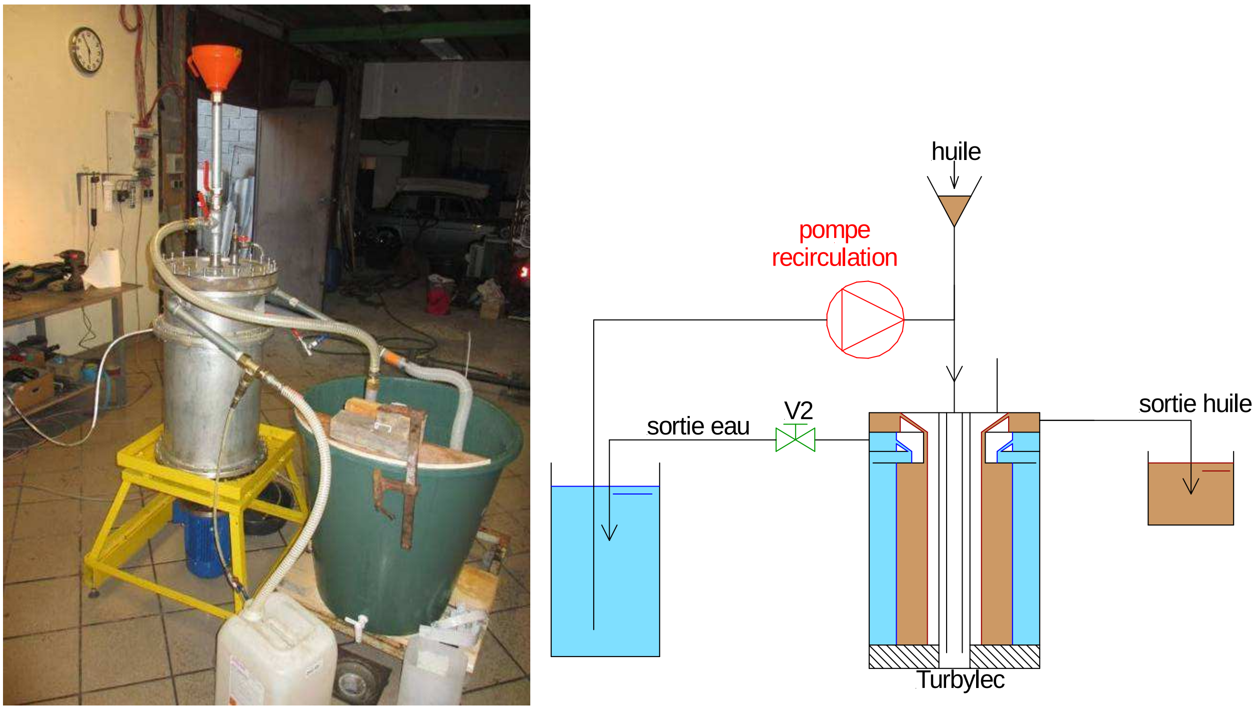


Figure 5: *Experimental configuration for optimization tests in Ruffieux.*

Qualification tests

Final qualification tests of Turbylec were carried out with the multistage skimming, pumping and separation system:

- Different type of oils:
  - low viscosity hydraulic oil
  - and moderated viscosity hydrocarbon
- Inlet emulsion flow:
  - Pumped by a volumetric pump
  - Or sucked using a vacuum pump
- Different types of mixtures treated:
  - Coarsely mixed oil and water flow obtained while pouring oil in a funnel at the separator inlet

- o Finely dispersed Oil in Water emulsion generated by the (skimming + pumping) system
- o Extremely finely dispersed Oil in Water emulsion produced by recirculation in a 200 litres reservoir with a relatively high pressure pump

o Volume of hydrocarbon/oil treated and type of water:

- o Few oil litres with a 200 litres fresh water tank
- o 10 litres HC with a 1250 litres fresh water tank
- o 50 litres HC with a 10 m3 litres seawater tank

First series of test (March 2013)

The multistage skimming, pumping and separation system is composed of the following elements:

- A conventional mechanical self-adjusting weir skimmer (DESMI Terrapin)
- A volumetric hydraulic driven lobe pump (BORGER AL25)
- The TURBYLEC separator

A first series of tests of this system were carried out with fresh water.

Figure 6: *Experimental configuration: skimmer + pump + TURBYLEC.*

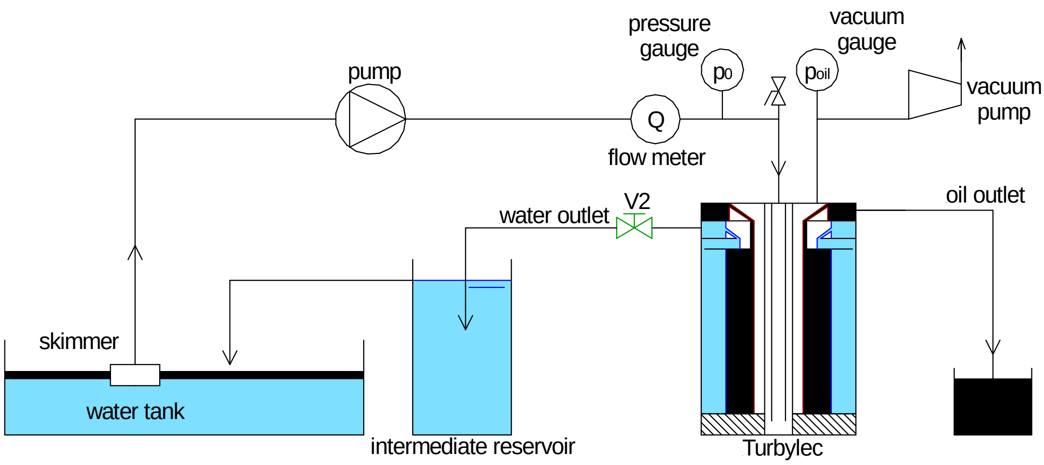


Figure 7: *Flow loop for experimental characterisation of skimmer + pump + TURBYLEC system.*

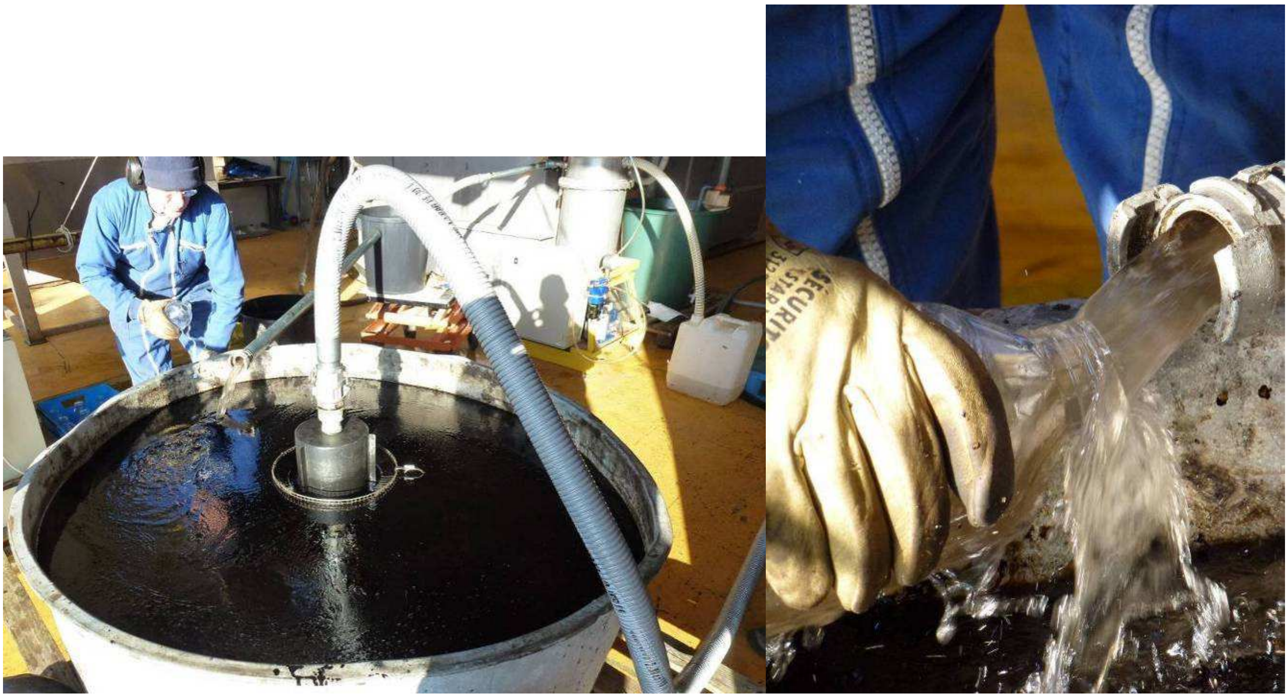


Figure 8: *Water sampling at water outlet.*

The main results is that the whole system can be considered as efficient for oil spill remediation both for light – low viscosity oils and for moderated density – moderated viscosity hydrocarbons, at least for inlet oil content below 20%.

In other terms:

- water produced at the separator outlet is sufficiently pure to be re-injected in the environment
- and oil collected is sufficiently pure to consequently drastically reduce the required storage volumes.

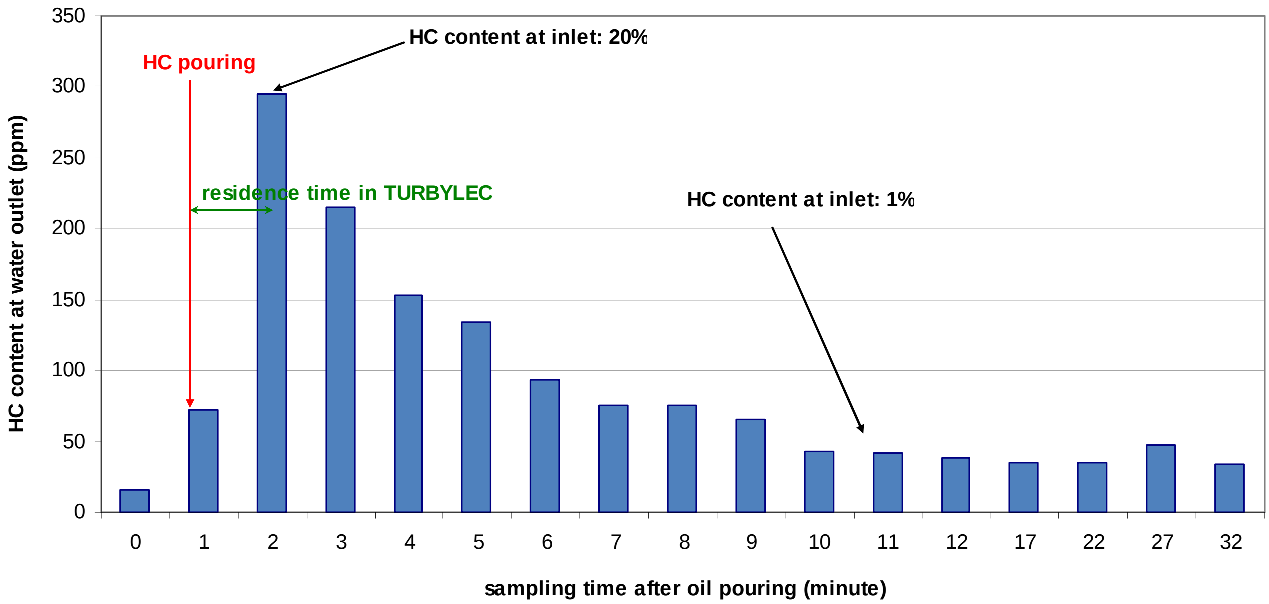


Figure 9: *Oil content in samples at water outlet.*

Second series of tests

Further separation tests were conducted in order to confirm the first results. These additional tests were performed with seawater and higher hydrocarbons volumes and concentration. The separation performances of TURBYLEC, operating at 45 l/min inlet flow rate, can be summarized as illustrated on Figure .

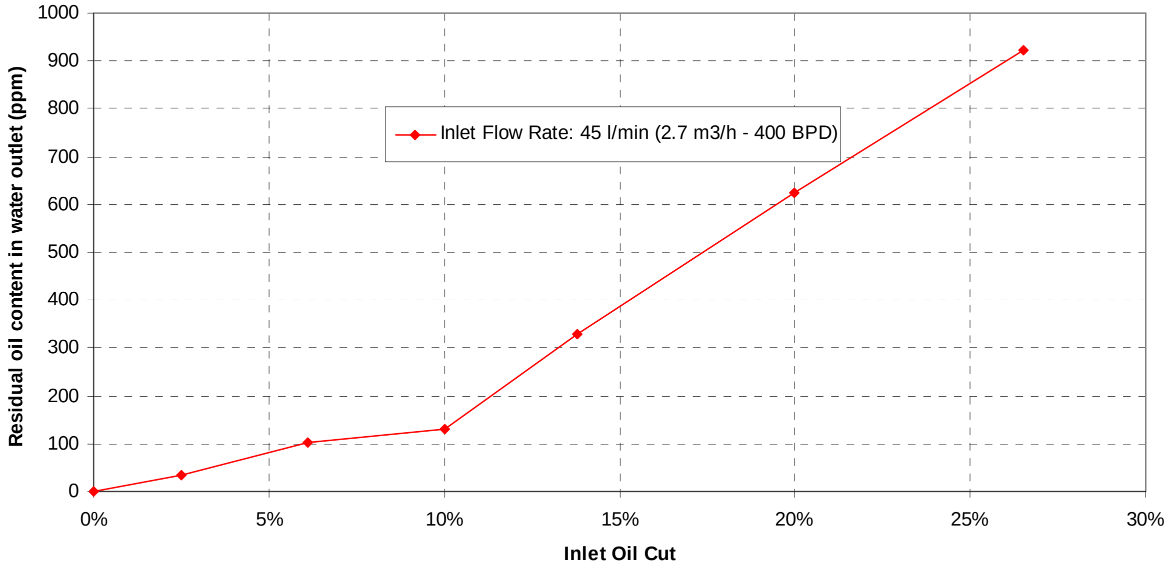


Figure 10: *TURBYLEC separation performances at 45 l/min inlet flow rate.*

For 20% inlet oil content, residual HC content at water outlet is limited to 600 ppm, which can be considered as very satisfactory for application to the Hoverspill project. These very good performances are maintained for inlet oil content up to 25% approximately. In this range of operating conditions the separator cut diameter was evaluated between 50 µm and 70 µm.

The prototype of innovative centrifugal separator TURBYLEC has a bulk (size and weight) compatible with its integration within Hoverspill platform. Tests results were very satisfactory showing that TURBYLEC matches with expected use (*i.e.* downstream of a non-selective skimmer, weir type and low flow rate) and has very good oil / water separation performances at least for inlet oil cut values up to 25%.

Hoverspill tests

Simultaneously to the action of the Turbylec, the Hoverspill ACV was tested in different oil spill simulation scenarios where it can also perform key tasks such as the transport of absorbing booms and confining barriers while the flat deck allows carrying goods or other material recovered from the intervention area, if needed.

Tests have been conducted on single devices and then on the assembled hovercraft. The main themes that were satisfactorily checked were:

- The functionality and performances of the soft-hull solution
- The functionality of the UNIK command and the RRS
- The functioning of the transmission with the hydraulic coupling
- The effectiveness of the lift system

- The ergonomics of the vehicle with the flat deck
- The ability of the vehicle in being the supporting base for oil-spill operations
- The limits of Hoverspill vehicle

The soft-hull system was checked first on smaller vessels (small boat and smaller hovercrafts) testing the functioning of the soft-hull made by the polyethylene skin and the foam hull. The functioning of the whole system indeed was checked in final tests on the hovercraft and gave satisfactory results for both impacting tests and parking on rough terrains.

The flat deck concept that is strictly correlated with the soft-hull concept was one of the most impressive out-comes of the project, in-fact this concept had a great impact on the operator's opinions. This concept is a real breakthrough in both the hovercraft and oil-spill field.

Flow reversers and rudders have been tested on smaller hovercrafts first and on a scale model next before testing on the Hoverspill vehicle in order to obtain the best solution for the RRS (Rudders and Reversers System). The RRS control surfaces were realized by a new system consisiting of a steel structure and low weight honeycomb panels.

Once the whole hovercraft was assembled, the first round of tests regarded the global functioning of the vehicle and the lift system in static condition. The hovercraft lifted correctly, air ducts and the lift system functioned properly while working in its static characteristic. The measured height of the vehicle on the ground was adequate.

A second assessment was carried on by turning on the vehicle with only the pilot on-board, measuring the trim of the vehicle such as to balance it. These tests had optimal results because it was possible to calibrate the lift-air and because the lift pressure ensures a lift of almost 1600 Kg.

The last static test was on bollard-pull and it was necessary to assess the thrust of the vehicle and the trim.

***Figure 11**: Bollard-pull test*

Main results achieved are: vehicle's thrust seemed to be good but had to be calibrated for high-speed tests. Optimal result appeared to be with a 35° pitch angle: the engine stops at 3950 which is the correct point of the MACP, the cooling system works quite well and the temperature of the engine is acceptable in any condition.

The dynamic tests have been performed on the Po River, in the north of Italy. To perform dynamic tests in water, special care was taken to apply a water-trap at the air intakes in order to prevent any waves to reach the fans in rotation.

The first test was performed starting from the shore and assessing the speed and the trim. The lift system denoted an important need of calibrated the lift-air.

Tests carried out on the Po River, revealed some adjustments that had to be performed:

- Calibration and partitioning of lift-air
- Stability checks in turn at speed
- Trim calibrations

Following tests performed at the extuary of the Loire River improved the ability of the hovercraft in passing the “hump-speed”. Hovercraft reaches the speed of 25kn. This result is good and acceptable but the ability of passing the “hump speed” is limited to particular conditions of the water. After a fourth test with a different pitch angle, the vehicle global mechanical and structural behaviour resulted to be good. No relevant problems were encountered and the hull check after tests on stones and rocks gave the positive results expected. Some adjustments had to be realized on the RRS system with the aim of improving the stability of the vehicle at high speed.

The functioning and effectiveness of the UNIK system gave quite good results. Functionality was correct and the vehicle could manoeuvre correctly but with the need of future studies to optimize the whole system effectiveness and efficiency.

Figure 12: *Hoverspill tested on river and at sea*

Figure 13: *Hoverspill tested in Paimbeouf, on the Loire river*

Final tests gave following main results:

1. The global functioning of the vehicle was correct and every system responded well.
2. Speed test gave appreciable results: hovercraft passes easily the hump speed, but tests were influenced by wind: against the wind the MACP finds difficult to pass the hump Speed.
3. A sensible inclining on the side during turning was assessed and corrected. But excluding the possibility of realizing the reverse thrust: future developments are needed
4. The handlebar gives the possibility of realizing very close manoeuvres with the aim of working in the oil-spill field
5. The behaviour at sea and on ground of the vehicle is as good as expected and its ability of going at high speed even in rough seas was verified
6. A high grade of ergonomics has been achieved by adopting some solutions on the vehicle such as the concept of flat deck, the modularity and the UNIK; the concept of flat deck permits the operators to move on-board with high agility and low risk for life safety. This represents a success for the project because no other ACV permits this high grade of ergonomics.

The potential impact

Hoverspill constitutes a revolutionary innovation in the field of environmental protection and conservation. Over past decades, crude oil and refined fuel spills from tanker ship accidents have caused serious damages to natural ecosystems in Europe and around the world. Marine oil spills can spread for hundreds of kilometers, destroying beaches and killing sea birds, mammals, shellfish and other organisms.

If pollution takes place off-shore, vessels usually don't reach the location quickly enough and the contamination expands rapidly. It becomes even more difficult when oil hits areas that cannot be easily reached by traditional vehicles, either by land or by sea, for the lack of water depth or because of muddy terrain. Hoverspill overcomes most of the these problems and, due to the easiness of its transportation, a single hovercraft can intervene on a potentially enormous area and it can even be stored far from rivers or beaches, becoming an additional operative vehicle in use for different rescue organizations.

***Figure 14**: Hoverspill's reduced dimension make it easy to move it fast wherever it's needed*

Based on the experience of Consortium partners, in case of oil spill intervention, Hoverspill reduces by 30% the total cost of shoreline remediation and it has been estimated that the European market can absorb about 200 equipped Hoverspill vehicles, with a unit cost being between €90 000 and €110 000.

An additional value is related to the MACP which was designed as a mobile chassis on which it can be installed any kind of gear and structure in order to be used in other situations. Properly equipped it can, for example, be used in flooding scenarios, for firefighting or police operations, or as an amphibious ambulance. It can also be used in geophysical surveying, or in environmental management, especially in wetlands, which are among the most vulnerable ecosystems but also the most difficult to access. Some possible scenarios were conceived in order to gain a better understanding of Hoverspill versatility.

Considering the potential use by fire brigades, flooding and rescue, amphibious ambulances, police, and water transport in general, worldwide production of 10 000 MACPs, variously equipped, and a revenue of over €700 million in five to seven years can be estimated.

Firefighting missions

Properly equipped, the MACP can become a key element in firefighting and rescue missions. A hydraulic pump can be installed on the flat deck in order to intervene quickly on the emergency area earlier than other vehicles. In situation where human life is in danger, every single second can mark the difference between a miracle and a tragedy: a fast intervention in a spot where a ship is burning with the consequent risk of explosion is a must. On both side of the hovercraft, life raft is installed in order to provide shelter for shipwrecked while waiting for extra support.

Being the hovercraft a vessel with no fans immersed in water, injured men can be easily taken on board by reducing the fan speed with a consequent lowering of the vessel to surface level without any risk. Even in the case of an unconscious person, the rescue mission is extremely easy.

***Figure 15**: Night-time rescue mission*

In order to be able to operate in presence of flames and very high temperature, the fire protection system envisioned by Hovertech is the turning point in the evolution of the MACP with rescue purposes. The system is made up by a pump which is connected with a so called “Cupola”. This system sucks water from sea at a safe depth and passes it to a sprinkler that covers all the hovercraft with a “Cupola” of water that protects the entire vehicle from flames, and heat.

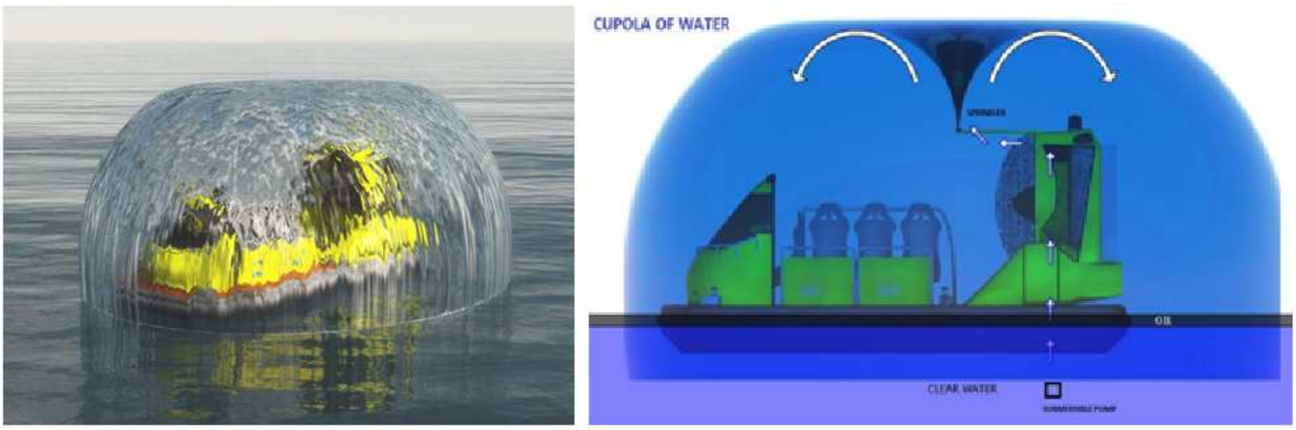


***Figure 16**: "Cupola" of water*

Ambulance and first aid

Similar to the firefighter setup, this configuration allows a fast intervention in those situations where human life is in danger and a quick response is needed. In this case, the modular body of the hovercraft is shaped in order to create a cabin where to recover the injured persons. The flat deck permits the load of emergency equipment and with a minimal change to the wiring system; even electric medical devices such as a defibrillator can operate.

Figure 17*: Emergency procedures with medical equipment*

Police actions

The flat deck makes it possible to set up a configuration with 6 seats for security purposes in all those areas hard to be reached by common vehicles. A team formed by up to 6 units can be transported on the hovercraft, with the possibility to allocate different agents: in some cases, police and medical forces have to work together and this configuration allows mixing up any kind of combination, with the chance to carry the proper equipment on the sides of the hovercraft.

Figure 18*: MACP in use for police squad team*

River areas with thick forest are probably the more indicated spot for this configuration. The hovercraft can travel at high speed, so it becomes possible to chase suspicious vessels, and the amphibious characteristic allows to act very effectively in case the runaway tries to reach the shore to escape on land.

Geophysical surveys

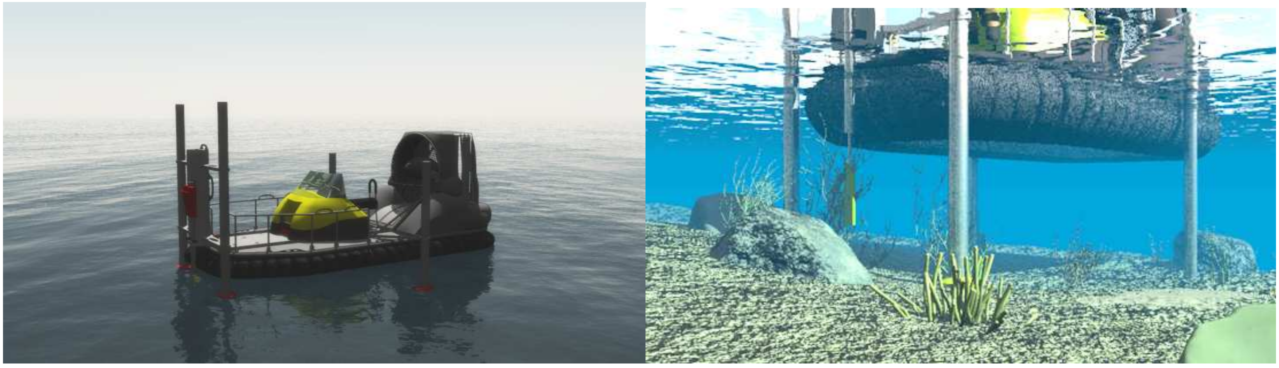


Figure 19: *Hovercraft set up for geophysical surveys*

A project for geophysical surveys has been drawn too. Some modification was required in order to set up a rig in the front of the MACP. This additional device made it necessary to remove the pilot's jockey seat and replace it with a special stool mounted almost in the center of the hovercraft. The gig is placed in horizontal position while cruising and then lifted by hydraulic joints when the probing point is reached. Surveys can be easily performed in rivers and swamps and the digging depth can reach up to 4 meters.

Leisure and tourism

Additionally to the professional use in emergency and scientifically research situations, the MACP can be equipped for leisure purposes. A configuration in this sense would have a jockey seat for the pilot plus 6 recliner for travelers. The resulting structure would be a closed cabin with windows on both sides and a translucent roof. An air conditioning system would be provided as well as the adaptation of proper safety devices. This kind of vehicle is perfect for big rivers in cities where civil transportation on water and tourism merge together (i.e. Dubai, Sydney, New York).

Dissemination activities and exploitation plan

Dissemination activities

The main dissemination activities carried out during project implementation can be summarised as follows:

1. Publication of 4 articles on local newspaper and a publication on studies and reports of the EU Transport. Joint articles are expected to be published after project conclusion
2. Several presentations to oil industries (TOTAL, SUEZ, etc), scientists, oil spill experts, policy makers
3. Participation with an own booth in 2 international Conferences (Romenvirotec 2012 and Interspill 2012).
4. Creation of a facebook page named "Hoverspill"
5. Creation of a commercial website www.hoverspill.com
6. 2 public field trials of the Hoverspill ACV
7. 1 public field trial of the Turbylec

Patents

- 1 patent application dedicated to the Turbylec separator has been submitted; inventors/authors: YLec Consultants.
- 2 patents dedicated to the MACP and the UNIK driving system has been submitted; invent/authors: Hovertech Ltd

Outline of the project exploitation

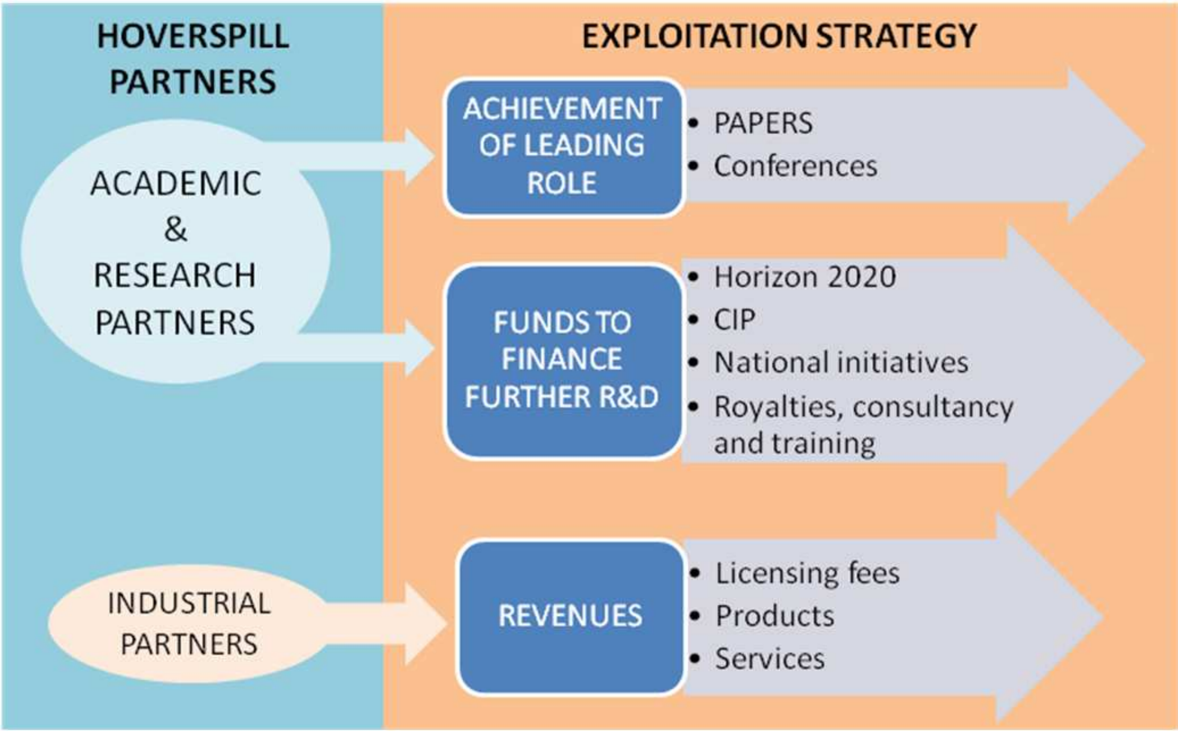
The consortium has developed a confidential exploitation plan with the aim to analyze the project's potential to create revenues and/or provide social benefits.

The identification of the project exploitable results represents the starting point of HOVERSPILL exploitation methodology which follows an analysis of each selected result in terms of:

- Market analysis for each potential product in terms competitiveness, innovativeness, time to market, further investments needed, price range(cost-benefit assessment);
- SWOT analysis in order to assess the whole prospective and potential achievement of the market targets.

The elaboration of the information collected for each exploitable result allowed to define the **exploitation potentialities** of the most advanced results and the **exploitation strategies** that Hoverspill consortium, composed by a variety of companies and organizations having heterogeneous core activities, missions and business focus, should undertake.

The figure reported below, gives a synthetic overview of partners' exploitation strategy grouped by categories.



The main exploitation guidelines emerging from the study are confidential and have been reported in the Exploitation Plan of Hoverspill, divided in two main sections:

- The consortium exploitation strategy, which gives a major outline of the exploitation of Hoverspill results based on a coordinated and integrated approach in which the whole consortium is involved

- The partners' exploitation strategy, developed in collaboration with each related partner, describes the approaches that the industrial partners will possibly undertake in order to bring Hoverspill products into the market.

Contacts

Project Coordinator: Dr. Federica Marotti
Organisation: INNOVA SpA, Rome, ITALY
e-mail: f.marotti@innova-eu.net
phone: +39 06 40040358
fax: +39 06 40040364
Project website address: http://www.hoverspill.eu

List of beneficiaries

Beneficiary	Organization	Contact Person	Email
1	INNOVA SpA	Federica Marotti	f.marotti@innova-eu.net
2	SOA	Paola Rigoni	Paola.rigoni@soanfibi.it
3	Cedre	Loic Kerambrun	Loic.Kerambrun@cedre.fr
4	YLec Consultants	Guillaume Maj	Guillaume.Maj@ylec-consultants.com
5	Terra Mediu	Paul Dogaru	terramediu@yahoo.com
6	Hovertech	Marco Mastrangeli	marco.mastrangeli@superhovercraft.com
7	University of Padua	Ernesto Benini	ernesto.benini@unipd.it
8	Centro Ricerche Fiat	Pierpaolo Del Gobbo	pierpaolo.delgobbo@fptpowertrain.crf.it