STREAMLINE

D41.5 – Final Report

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Abbreviations Used in this Document

Abbreviation / acronym	Description
WP	Work Package
CRP	Contra-rotating Pod
ICP	Integrated Contra-rotating Pod
LAP	Large Area Propeller
RANS	Reynolds Averaged Navier-Stoke
SoA	State of the Art
PSS	Pre Swirl Stator
VG	Vortex Generator
BLAD	Boundary Layer Alignment Device
VOF	Volume of Fluid

1. Executive Summary

The objectives of the STREAMLINE project were to:

- Demonstrate radically new propulsion concepts delivering a step-change improvement of at least 15% efficiency over the current state-of-the-art.
- Investigate how to fully optimise current state-of-the-art systems including conventional screw propeller systems, pods and water jets.
- Develop advanced CFD tools and methods to optimise the hydrodynamic performance of the new ship propulsion systems, particularly by analysis of the integrated hull and propulsor.
- Characterise the operational aspects of each of the radically new propulsion concepts

These aims were addressed by focusing on 3 main areas:

- WP1 - New Propulsion Concepts which included:
    i. Large area propulsion system,
    ii. Biomechanical system
    iii. Distributed thrust system.
- WP2 - Optimisation of State-of-the-Art Propulsion which included: i) advanced screw propeller systems, ii) high-efficiency water jet at low speeds and iii) advanced pods.
- WP3 - CFD Methods and Tools.

The four year project completed in February 2014 with the following key outcomes:

- Analysis and tank tests have shown the Large Area Propeller achieving an efficiency improvement of between 12.5% and 15% with respect to the baseline.
- Large scale demonstrator testing of the biomechanical system was not possible during the project. However, significant CFD modelling was performed which indicates that the Walvisstaart propulsor in a vertical position is producing effective self-propulsion.
- CFD analysis and model tests indicate that the final performance of the vessel fitted with distributed propulsion was improved by approximately 25%.
- Results from the advanced screw concept indicate that large improvements of hydrodynamic performance are achievable and this concept would be viable to new builds.
- The work on the water jets has shown that although low speed performance can be improved, there is a significant detrimental impact on performance at high speed. However changes to the concept have been identified that could potentially improve the performance of the inlet leading to better high speed performance.
- The advanced pod concept was shown to have significant potential for improved efficiency,. With the predicted power for the contra-rotating propeller being 13.5% lower than the reference ship.
- A number of CFD tools were developed in STREAMLINE which have been shown to have the capability to be used for design tools within industry, with a reduction in computational effort and the operator skill required along with a corresponding increase in the ability to model complex geometries .

2. STREAMLINE Concept and Objectives

Increasing environmental concerns and soaring oil prices are creating a new focus on fuel efficiency for the marine industry. Low emissions with demands for more advanced vessels than ever before drives the need for radically new propulsion concepts delivering a step-change in efficiency. STREAMLINE has been the response of the marine community to this demand.

The STREAMLINE project was broken down into 3 main areas:

- WP1 - New Propulsion Concepts;
- WP2 - Optimisation of State-of-the-Art Propulsion;
- WP3 - CFD Methods;

2.1. WP1 - New Propulsion Concepts

The first major objective of STREAMLINE has been to demonstrate radically new propulsion concepts, delivering a step-change improvement in efficiency of up to 15% over the current state-of-the-art.

The aim of STREAMLINE was to develop these concepts in both design and operational analysis to maximise the potential efficiency increases and translated potential cost saving to the end user.

This work package was split into three smaller work packages to develop three individual concepts:

- WP11 – Novel Application of the Large Area Propeller
- WP12 – Biomechanical Systems
- WP13 – Distributed Thrust

2.2. WP2 - Optimisation of State-of-the-Art Propulsion

In addition to considering new and more efficient propulsion concepts, there are many opportunities to optimise existing propulsion technologies and it is widely believed that reductions in fuel consumption and noxious emissions can be obtained.

The second major objective of STREAMLINE was to investigate different methods to fully optimise current state-of-the-art (SoA) systems including conventional screw propeller systems, pods, rudders and hull configurations, and water jets:

- For conventional screw propellers, and using advanced CFD tools; the study included the optimisation of blade shape and of special components such as propeller ducts, as well as inflow improving devices such as pre-swirl stators, vortex generators, equalizing ducts and rudder configurations by introducing twisted rudder designs. The performance of the optimized configurations was verified through an extensive experimental campaign and the reliability of CFD-based design tools developed within the project was assessed.
- For advanced pods; STREAMLINE focussed on the benefits of using pods in contra-rotating concepts (CRP), both improving the CRP-pod concept (single podded screw behind a main propeller) and the integrated contra-rotating pod (ICP). Using the new tools developed within the project, STREAMLINE investigated the use of the podded propulsor in different configurations on the ship's hull, where previously the high risks of ventilation could not be properly assessed and avoided.
- For water jets the aim was to deliver higher propulsive efficiency over a wider range of operational conditions.

This work package was split into three smaller and more focussed work packages:

- WP21 – Advanced Screw Propeller Systems
- WP22 – High-Efficiency Water Jet at low speed
- WP23 – Advanced Pods

2.3. WP3 - CFD Methods

To achieve its first two objectives, STREAMLINE had to have access to new tools and methods for modelling performance aspects of propulsion technologies.

Consequently, the third major objective for STREAMLINE was to continue the development of advanced CFD tools and methods to optimise the hydrodynamic performance of the new ship propulsion systems. The CFD tools developed were used throughout the STREAMLINE project.

This work package was split into five smaller work packages to develop the CFD methods and tools:

WP31 - Development of Fixed-grid / Rotating-grid Coupling

WP32 - Grid Adaption

WP33 - Prediction of cavitation

WP34 - RANS / BEM Coupled Method

WP35 - Design Optimisation

3. Results and Foreground

3.1. WP11 – Novel application of the Large Area Propeller

By increasing the propeller diameter the propulsive efficiency is increased, but the size is limited by hull restrictions, and the difficulty is how this concept is applied to a vessel.

3.1.1. Design, optimisation, analysis and model testing

STREAMLINE has developed ways in which the Large Area Propeller can be configured on a vessel which are outside the conventional constraints of design. For example, placing the propeller below the baseline, and aft of the transom decreases the margin against ventilation.

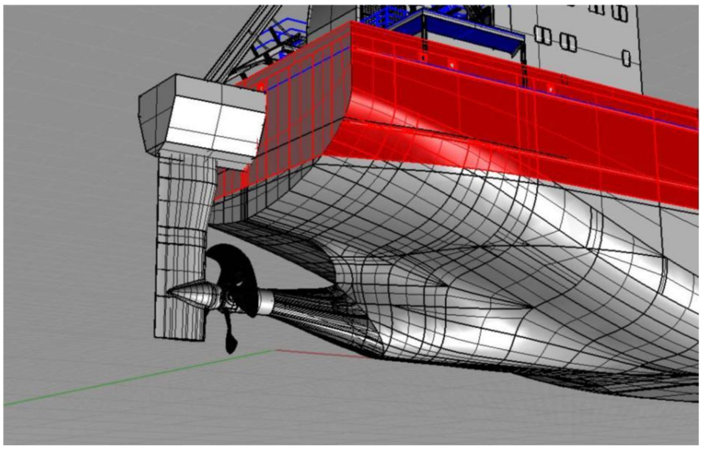

Figure 1: Large Area Propeller (LAP)

The Inclined Keel Hull concept (IKH) has also been developed, where the propeller is in a conventional position under the ship, but there is an incline to the hull of 0.5 degrees.

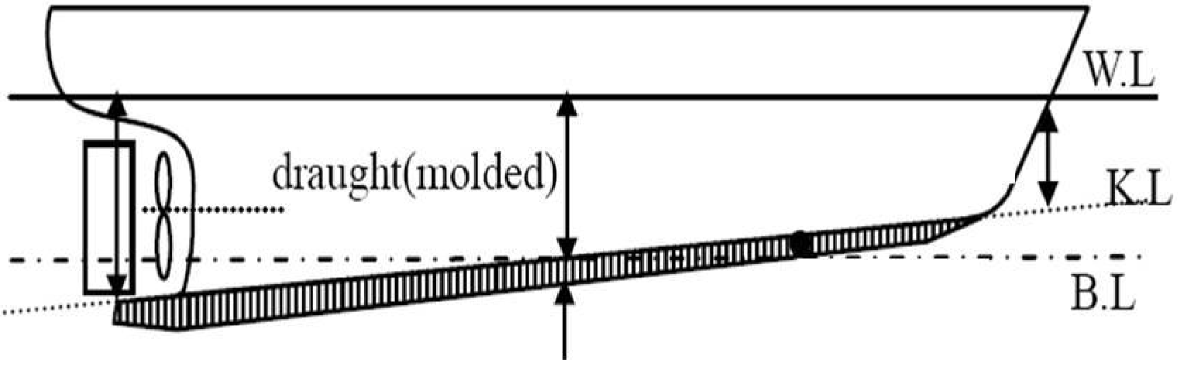

Figure 2: Inclined Keel Hull Concept

Moving the propeller aft and increasing the area indicated a great potential for power reduction. From the resistance and self-propulsion tests it was found that the LAP for the optimised conventional variant of the 8000 DWT tanker showed some 13.5 % lower power consumption compared to the original design at design speed and up to 17%, at full power.

From these original results, attempts to further improve the configuration were then analysed. Firstly, systematic changes of the skeg/boss were carried out and an elongated boss stretching back to the propeller was found to be best, with a power reduction of 1% compared to the original hull with a long shaft to the propeller. This hull was then model tested at SSPA. Thereafter, a study was made of a bracket configuration, where one of the brackets was systematically turned to yield a pre-swirl of the inflow to the propeller. It was found that the power can be reduced compared to the case with brackets aligned with the flow, but the reduction was not large enough to compensate for the additional friction of the brackets.

As an alternative to the shafted propeller, a study was then carried out with a POD propulsion system and a modified hull, see Figure 3.

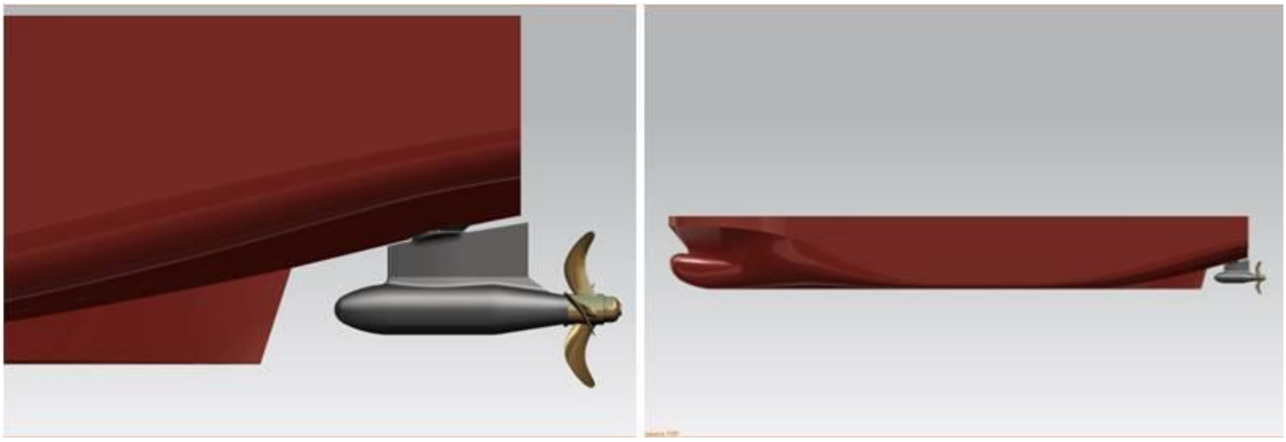

Figure 3: Podded LAP and Optimised Hull Configuration

Systematic changes of the hull in front of the POD resulted in a small reduction of power, as did the introduction of stabilizing fins instead of the skeg. However, the improvements were within 0.5%. The computed results indicated a gain in power between the best POD case and the original optimised hull by approximatley 3%.

Validations were completed, both for the computational technique with a zonal approach, used in all systematic computations, and a technique where the viscous free surface is modelled in the RANS code (VOF technique). Comparing the original propeller/hull configuration with the optimised hull/extra- large area propeller, the reduction in propulsive power was 15.0% for the zonal approach and 13.4% for the VOF approach. This should be compared with the gain of 14.2% in the SSPA tests. There is thus good correspondence between all three results. Full scale computations (zonal approach) indicated a somewhat smaller gain: 12.5% which should be compared with 13.5% for the extrapolated SSPA data obtained from the ITTC scaling procedure.

Ventilation studies were finally carried out using the ISIS-CFD flow solver by ECN/CNRS. A validation study was first carried out for a generic test case reported by RRHRC, where a propeller was run at a different submergences and rates of revolution below the free surface in a tunnel. Qualitative agreement with the data was achieved. Thereafter, seakeeping computations were carried out for the optimised 8000t tanker with the extra-large propeller at different sea states corresponding to tests at SSPA.

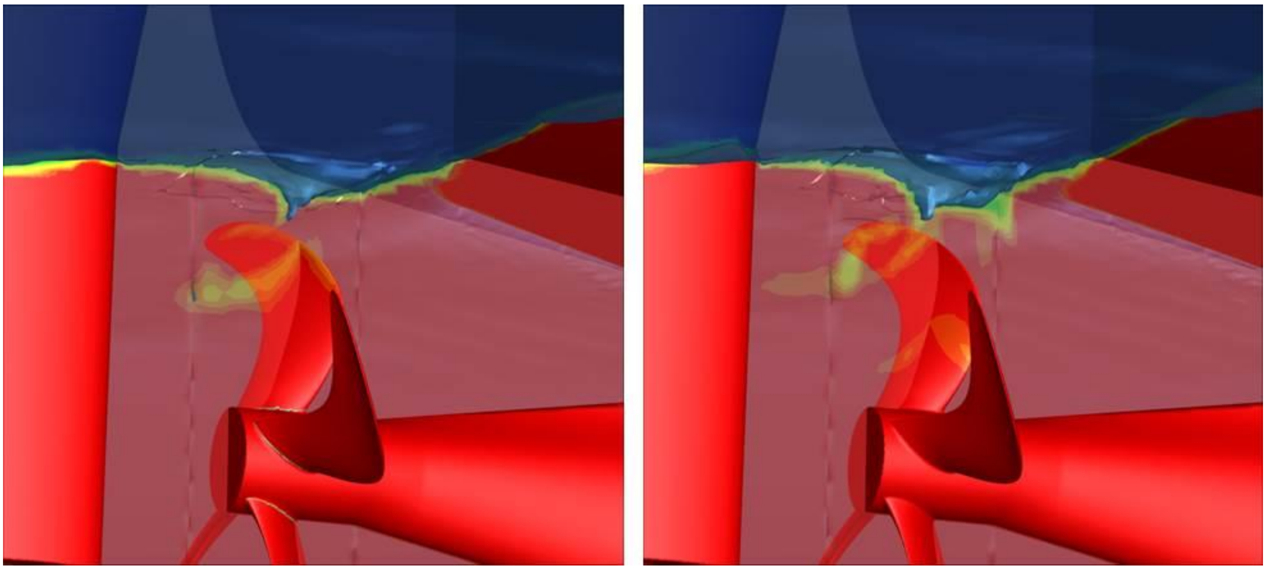

Figure 4: Example of computed ventilation occurring for model scale (left) and for full scale (right).

These tests verified that the assumed high efficiency for the concept can be expected in full scale. A reduction in propulsive power of about 15 % compared to the original design is a very big improvement. The tests also revealed that there is no problem with cavitation or high pressure pulses to be expected, manoeuvring properties are also good.

3.1.2. Inclined keel hull concept

The Inclined Keel Hull studies have addressed many of the operators concerns; propeller above baseline, moderate trim within capacity of existing on board ballast systems and propeller shaft speed within range of existing engines. The results from model test verification revealed a 4.3% maximum saving in the delivered power whilst the saving was 4% at the design speed. The findings confirmed the numerical predictions for power saving and hence supporting the worthiness of the IKH concept for the design applications of large commercial vessels.

3.1.3. Optimised Configurations Single screw propulsion

The objective was to perform power prediction using physical or real propeller geometry rotating in real time, which included full transient calculation.

Four different aft ships propulsion arrangements have been studied:

1. Single screw,
2. Twin screw Azipull,
3. Twin skeg – twin screw with conventional propellers,
4. Single screw with CRP (Contra Rotating Propeller - Azipull thruster behind a single screw propeller).

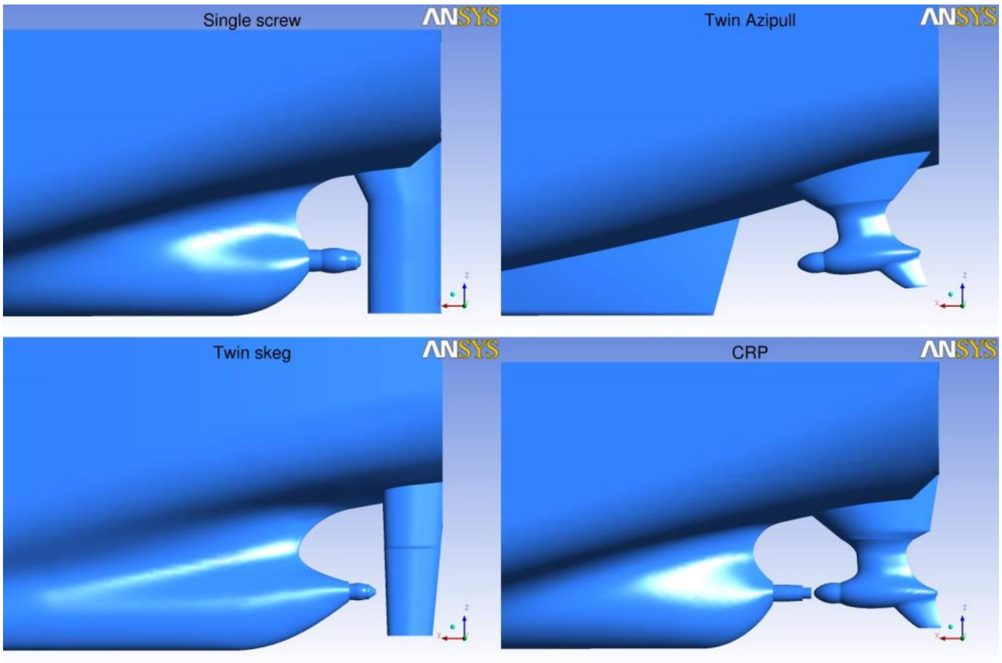

Figure 5: View of the four configurations without propellers

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The selection of an optimal aft ship configuration for a specific application or operational profile type becomes ever more important to reduce fuel consumption and emissions and at least to add value to the ship owner.

In Figure 6 the delivered power results of the sliding mesh CFD calculations are compared against their respective model test result. No model test results are available for the contra rotating propeller configuration (CRP) though. The results are normalised with the model test results for the single screw configuration – the reference vessel.

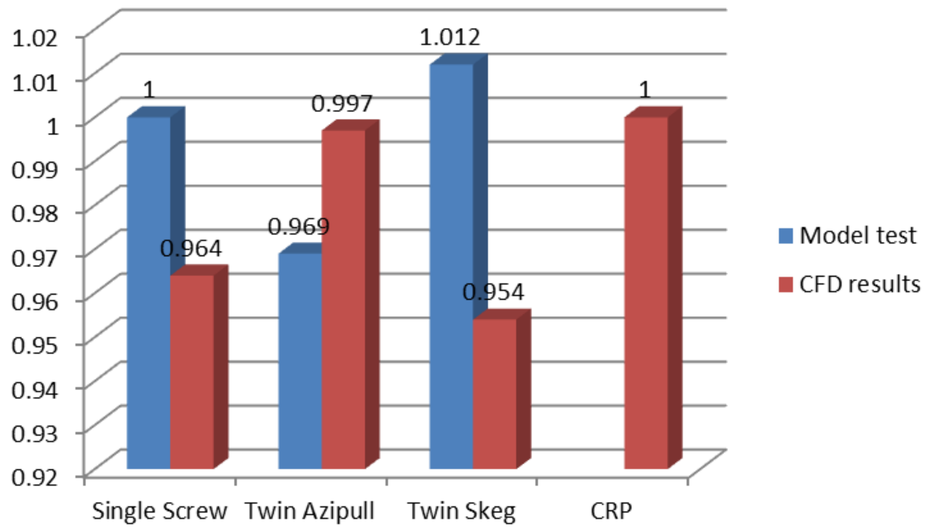


Figure 6: Comparison CFD results against model test results for the four configurations

The ranking between the various aft ship configurations are obviously different in model test and CFD. It is difficult to state what effects explains the deviation. Some reasons could be:

- CFD analyses are performed in full scale and are compared with scaled model test results. There might be uncertainties in the scaling procedures from model test.
- The meshes in the CFD models might not have sufficient resolution in critical areas and there could be inaccuracy in the numerical schemes.
- Certain flow phenomena might not be captured in the CFD models, either by mesh or numerical schemes. There might be deviation in the geometry used in model test and CFD.

Before start of analysis the CRP configuration was believed to be the most efficient propulsion concept. With an aft propeller regaining the energy from the swirl of the front propeller, higher propulsion efficiency is expected. From the CFD results we actually see that the CRP hull has the highest delivered power. One reason is that the hull resistance is higher since there is more curvature in the aft body to make room for the propulsion system.

Different trends in the CFD results compared model tests and some uncertainties about the model tests make it difficult to rank the configurations. Having to choose figures for the LAP benchmark, the model test results will be used for the twin azipull (gain +3%) and the twin skeg (-1%). For the CRP the CFD results have to be used (gain -4%)

3.2. WP12 - Biomechanical System – The Walvistaart Pod

As a radical move away from conventional propellers, STREAMLINE has researched and developed the Walvisstaart Pod concept (WSP).

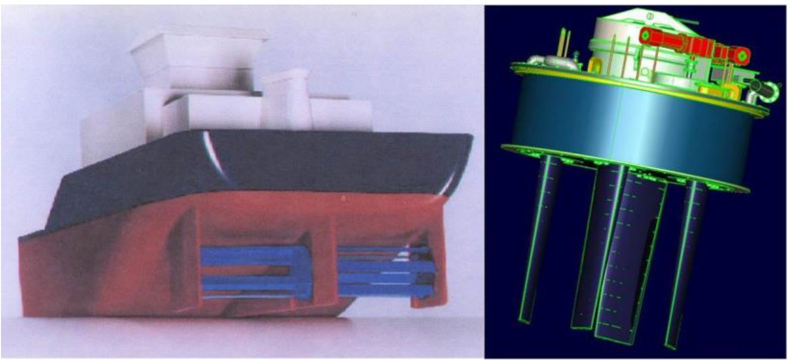


Figure 7: WSP Concept development

Throughout the project, the WSP concept has been developed and improved. The hull lines of the outer hull have been designed for the WSP unit in the horizontal orientation:

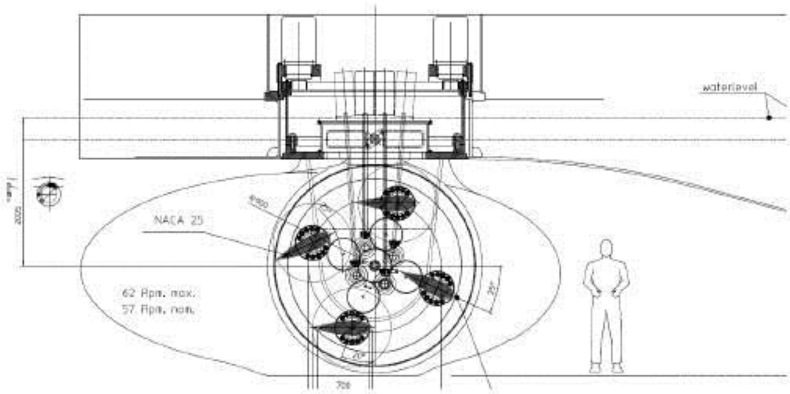


Figure 8: Side view of the aft ship WSP in horizontal orientation

The main ship dimensions of the design are fixed at the typical Inland Waterways ship dimensions:

Loa = 110.00 m, Beam = 11.45 m, Depth = 5.55 m, at a maximum draught of 3.55 m.

The hull lines were optimised by MARIN using a non-linear potential flow programme RAPID. This programme computes the wave pattern and the inviscid flow along the hull to fully non-linear boundary conditions on the water surface. In the calculations, the dynamic trim and sinkage of the vessel have been computed and the hull attitude has been adjusted accordingly, to take into account their effect on the wave making.

A feasibility study of the direct drive system was completed. Comparisons were made between three different drive systems:

- Mechanical transmission: Using a diesel and connecting to a reduction gearbox.
- Hybrid Transmission: Using a diesel generator to drive a electro servo drive system.
- Direct Drive: Using a diesel generator and electro magnets to drive the blades.

Comparisons were made on these three systems in:

- Efficiency
- Reliability
- Design
- Cost
- Maintainability
- Flexibility
- and Safety.

It was concluded that the direct drive system is the most suitable solution for a rotating main wheel with four blades. This system was demonstrated to be the most efficient and economical manner to transmit the power to the blades. The main advantage being that this system would not require much maintenance, unlike the other concepts. This is due to the absence of mechanical parts.

Once the hull lines and the feasibility study had been completed, a detailed design of the WSP was completed, which included the following design points:

- The required efficiency improvement of 20-30%;
- Deformation at gearwheels and sealing;
- Lifetime of bearings and gearwheels;
- Stress and deformation of drive components;
- The ability to produce and mount the designed components;
- Cooling of the direct drive system;
- Sealing of the pod;
- Lubrication of the gearing;
- Control systems.

Within the original description of work, the operational testing of a full scale version of the Walvisstaart Pod was envisaged. The previous work completed in the detailed design was planned to be fed into the manufacturing process for the construction of the Pod and a suitable vessel, this would have been conducted outside the project and would have been funded by Walvisstaart. After the project completion, this vessel would have then been used by Walvisstaart to demonstrate the viability of their design and operational performance of the system. However, as a result of the financial crisis, Walvisstaart were unable to raise the necessary funding and the work was therefore not completed.

The structure of the work package was therefore changed to focus on the following aspects:

- Detailed design of the WSP in model scale;
    - Hydrodynamic aspects,
    - The blade motion patterns,
- Model scale WSP vessel design;
- Model scale construction, testing and evaluation.
- CFD computations to find operational performance and to validate the results.

3.2.1. Model scale design and testing

As the WSP is a complex system, MARIN first did a feasibility study to investigate if such complex system could be developed within the available time and budget. MARIN has completed work on the early design of the model test set-up. Within this design stage the following areas have been researched:

- How to measure the forces and dynamic loads applied to the blades;
- Electric mechanical drive and Direct electric drive;
- Scaling;
- Tolerance of the gears;
- Loading;
- Accuracy required.

There were uncertainties in the complex rotation of the blades, control systems, system tolerances, rotating reference disk, as well the level required for measurement accuracies. These uncertainties posed serious risks for the viability of the study which could have been solved if more time was available in the STREAMLINE project. As a result, the model scale design and testing by MARIN was discontinued.

3.2.2. CFD computations of operational performance

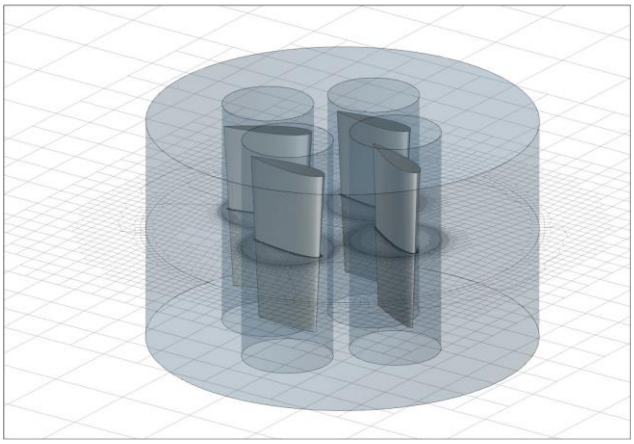
The aim was to apply the potential of enhanced CFD-based modelling developed within STREAMLINE to the WSP concept in full scale conditions.

Three progressive subtasks were therefore devised:

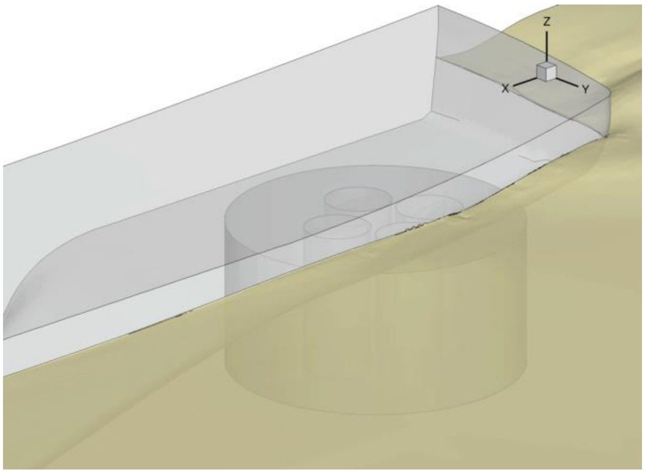
- Feasibility studies from 2D simplified model

This step was mandatory to precisely evaluate the risk in terms of possible CFD limitations. The dynamics of the WSP were precisely defined concerning the laws of motion in time of the rotating and oscillating bodies.

- Create a 3D numerical model of the ship and WSP. Precise definition of the ship and location of the WSP have to be defined relative to the ship hull.



- Simulation: model scale in design condition at prescribed trim & sinkage.



This CFD demonstrator, although not compared to measurements from model scale tests, shows that the considered Walvisstaart propeller in a vertical position is producing effective thrust and self-propulsion can be obtained. However, better knowledge of the flow is missing, particularly with regards to the impact of the shedding of strong vortical structures on the efficiency. Considering the flow complexity with interactions between the blades (vortices and boundary layers), the other uncertainty is in the turbulence modelling and the limitation in RANS approach. This is why it is mandatory for numerical simulations involving such complex geometries and flow conditions to be validated with model tests results.

3.3. WP13 - Distributed Thrust

Highly loaded propulsors that deliver poor efficiency are a feature common in many ship types including inland waterways vessels, fast ships and tug boats. An emerging alternative to the large area propulsor concepts highlighted earlier is to distribute thrust over multiple propulsors arranged around the ship hull:

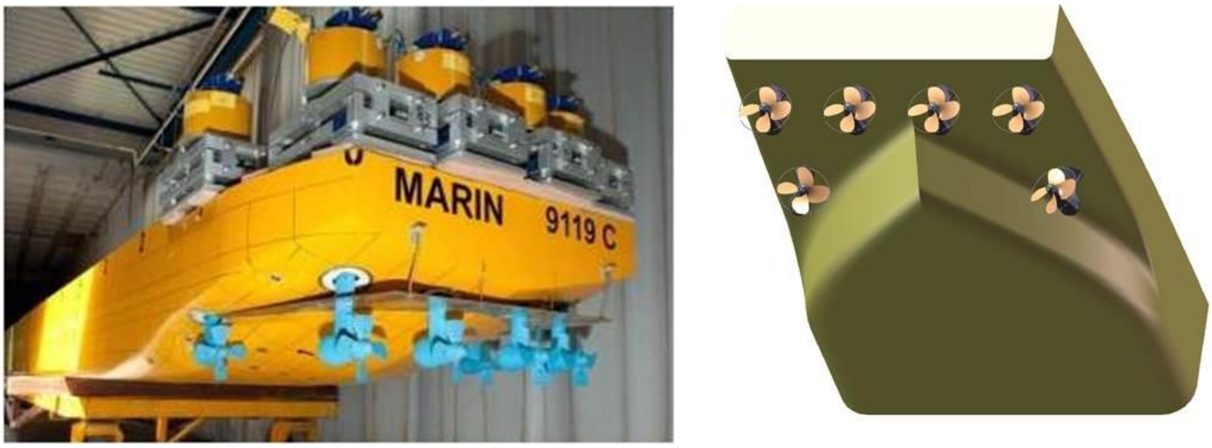


Figure 9: Distributed Thrust Arrangements

The objectives of this area of research were to:

- Develop new methodologies to better predict air suction - a major factor affecting the hull design and size of the propulsors - and in this way improve propulsion efficiency.
- Carry out CFD modelling to derive the optimal distribution of multiple thrusters around the hull.
- Validate the distributed thrust concept with its optimal propulsors configuration through model testing.
- Evaluate the efficiency gains measured against benchmarks

The findings of WP13 have been assessed by the comparison with the experimentally investigated benchmark ship and the fully developed distributed thrust concept:

- CFD optimisation of the bare hull reduced the resistance by 22%, which is more than the 16% predicted.
- The developed of the hull displaces 3% more water, which can be exploited by a higher payload.
- CFD codes from WP3 to predict ventilation of the propellers were applied and validated successfully in this WP.
- A required thrust reduction of 38% has been found. However, due to a poor efficiency of the applied rudder propellers and stock propellers this significant thrust reduction leads to a power reduction of only 7%.

With the knowledge achieved within STREAMLINE work packages and the foreground knowledge gained, it was deemed feasible to exploit more than the thus far determined 7% power reduction; in particular when taking into account that the thrust demand was reduced by 38%. Therefore, the optimisation of the used rudder propellers was decided upon.

With the optimisation of the rudder propellers, the open water efficiency of the rudder propellers was improved by 21.5%, consequently the final performance of the vessel was improved by approximately 25%, while providing an increased cargo carrying capacity of 3%.

3.4. WP21 - Advanced Screw Propeller Systems

A primary aim of the STREAMLINE project was to develop and evaluate innovative marine propulsion concepts to achieve significant alleviation of environmental impact as well as reduction of operational costs. Nevertheless, it has been shown that enhanced CFD modelling/design techniques represent a powerful means to pursue consistent improvements of standard screw-propellers efficiency, without incurring major modifications to the overall propulsion layout.

The aim of this work package has been to explore the potential of enhanced CFD-based modelling and design techniques to achieve a new generation of high-performance screw propeller systems, these included:

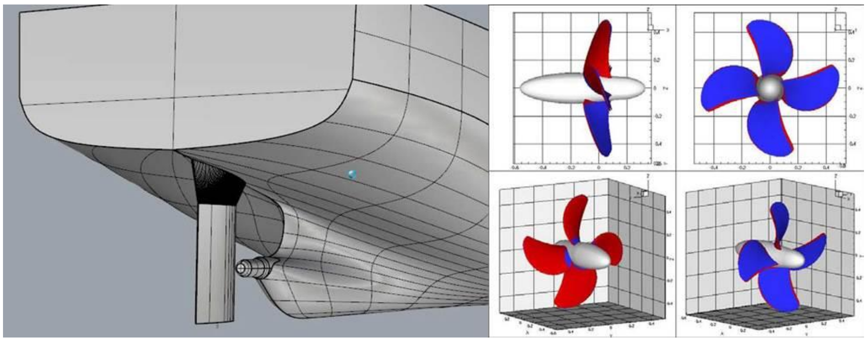


Figure 10: An optimised hull aft body and corresponding propeller.

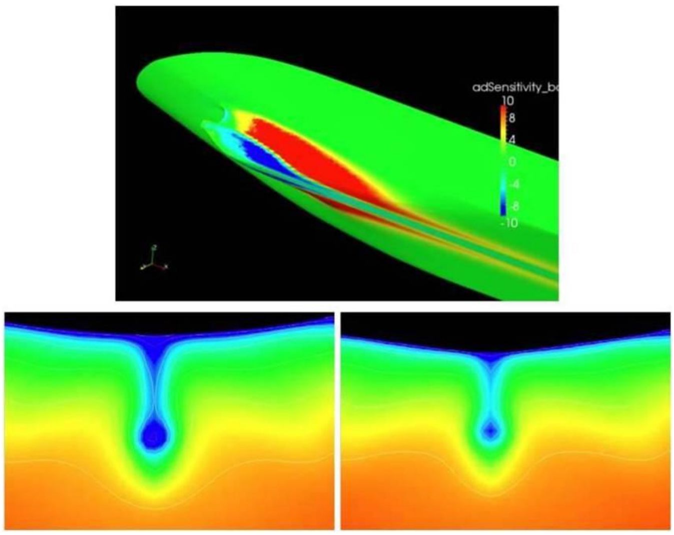


Figure 11: A propeller optimised for the original hull form.

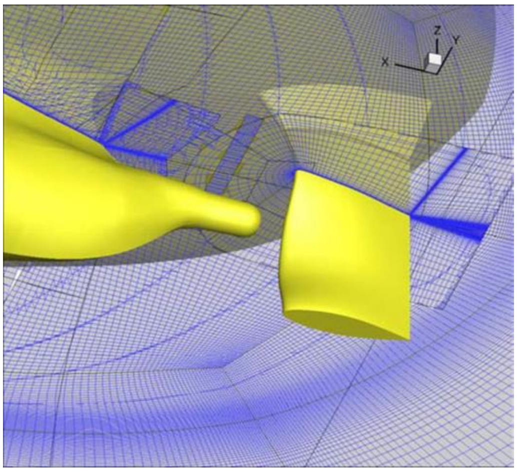


Figure 12: An optimised propeller / rudder layout based on the twisted rudder concept.

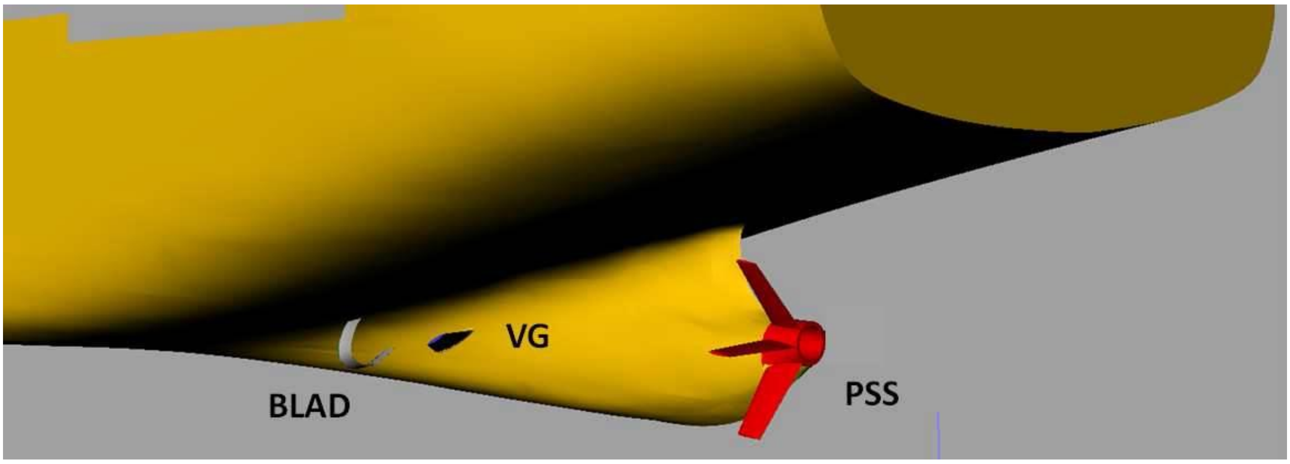


Figure 13: Three alternatives inflow improving devices

- Vortex Generator (VG)
- Pre-swirl Stators (PSS)
- Boundary Layer Alignment Device (BLAD)

The analysis of model test results has allowed STREAMLINE to draw the following main conclusions for each of the design modifications addressed:

Optimised hull aft body and integrated propeller (H2+P2)

Results demonstrate that a totally new hull aft body design obtained by advanced CFD tools can determine large improvements of hydrodynamic performance. In this case, modified hull lines have been designed to fit a larger diameter propeller while preserving hull displacement and tip clearance of the baseline design. Delivered power at full scale (PDs) has been increased by 8.7%, and the inflow to the propeller is more homogeneous with lower pressure pulses and vibratory loads with respect to the baseline.

Tip-raked propeller (P3)

A tip-raked propeller (P3) optimised for the original hull form has achieved an increased open water efficiency of more than 3%. Unfortunately, efficiency gain at advance ratio corresponding to ship cruise speed is marginal and hence no improvement of delivered power PDs is observed while design propeller RPM is reduced about 1%.

Twisted rudders and pre-swirl stators

Two optimised propeller/rudder layouts (R1LE and R2) based on the twisted-rudder concept determine a reduction of PDs of approximately 1%. Similar power gains are obtained by introducing a pre-swirl stator (PSS) with 3 fins on portside.

3.4.1. WP21 Advanced Screw Propeller systems

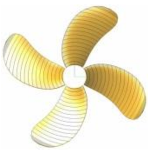
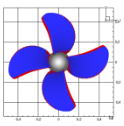
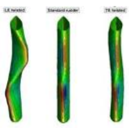
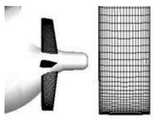
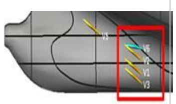
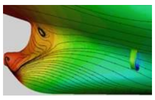
Reference Ship case: Hull (H0)+Propeller (P0)+Rudder (R0)						
	Propellers		**Twisted Rudder**	**Inflow improving devices**		
	P2	**P3**	**R1**	Pre Swirl Stator (**PSS**)	Vortex Generator (**VG**)	Boundary Layer Aligning Device(**BLAD**)
						
Modified Ship Cases	(**H2**+**P2**+R0)	(H0+**P3**+R0)	(H0+P0+**R1**)	(H0+P0+R0+**PSS**)	(H0+P0+R0+**VG**)	(H0+P0+R0+**BLAD**)

Figure 14: WP21 Advanced Screw Propeller systems

3.4.2. Operational analysis

The operational analysis review indicates that the simplicity of the modifications to improve hydrodynamic performance of the reference vessel would mean that very little change would occur to the vessel. This in turn makes all the different 'Advanced Screw Propeller systems' concepts practically feasible options due to their inherent passive functioning for both new building or retrofitting purposes.

3.4.3. Cost-benefit analysis

Cost benefit analysis indicates that among the different 'Advanced Screw Propeller System' concepts, the P2 Propeller option combined with hull modification (H2) is more economically viable, but can only be applied to new builds. Out of the remaining concepts, which are all indeed retro-fit options, twisted rudder R1 is more economically viable.

3.5. WP22 - High-Efficiency Waterjet at low speeds

Water jet systems have been used for propulsion of vessels in the whole speed range up to, and even beyond 55 knots, with main applications in the speed range 25-45 knots. For lower speeds than 25 knots the industry relies mostly on propulsion systems based on conventional propeller technology. The combined needs of reduced fuel consumption, lower emissions and increasing demand for high vessel speeds leads to the need for new conceptual designs handling dual design targets both at high and low speed.

It has been the aim of STREAMLINE to investigate the potential to design high efficiency waterjet systems based on variable inlet/outlet geometries using existing and new actuation technology.

A number of different concepts have been evaluated until a single concept which was promising and realistic was found and was then taken forward to final design. This concept had an auxiliary channel that could be either active or passive:

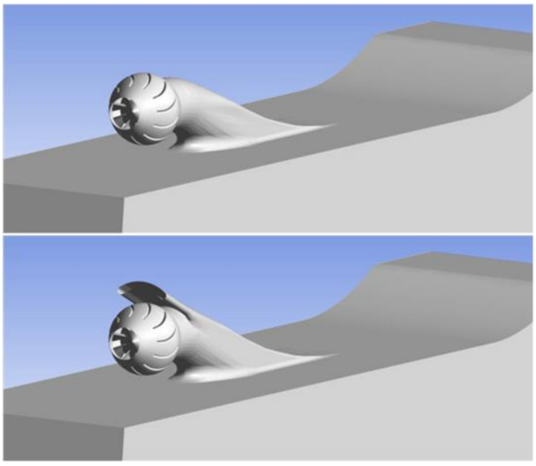


Figure 15: Auxiliary Channel Concept

Model testing in a towing tank, cavitation tunnel tests, as well as CFD simulations have been carried out and the final design to evaluate the classification and operational aspects of the concept.

Figure 16: Cavitation tunnel testing

During initial model tests in the cavitation tunnel it was shown that significant improvements in low speed efficiency were displayed, however at high speed the performance has not been as intended with a reduction in efficiency compared to the baseline.

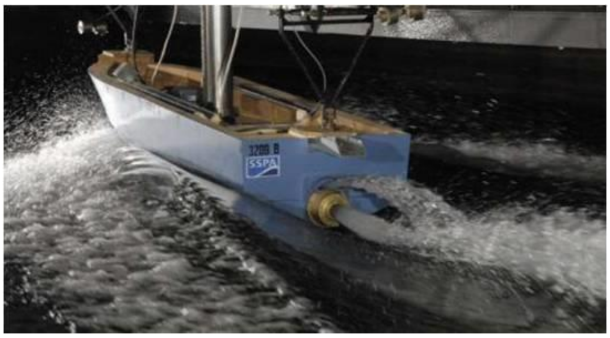


Figure 17: Model Testing

Using the towing tank facilities at SSPA, both towing tank and self-propulsion tests were carried out. The results showed a good collaboration with the results previously obtained in the cavitation tunnel at the higher speeds which meant that the baseline inlet performed better than the new design, both with the auxiliary channel opened and closed. During bollard pull testing, no differences were displayed between the inlets but this is likely a consequence of the towing tank tests being performed at atmospheric conditions where the pump and inlet cavitation does not block the pump in the same way as it would do in the reduced pressure in the cavitation tunnel.

The numerical simulations of the bare hull resistance and self-propulsion tests showed a good agreement with the cavitation tunnel and towing tank tests, but some deviations were found in the results. These deviations in the results may have been due to a short fall in the simulations.

The operational and cost benefit analysis showed that the performance increase at low speed did not compensate for the losses at high speed, and thus there is no incitement for an operator to invest in the design, this is due to the increased production cost not being recuperated through the reduced fuel consumption. Improvements to the concept have been identified that could potentially improve the performance of the inlet but this would be at an additional cost in the manufacturing process.

3.6. W23 - Advanced Pods

Pod units have been used for ship propulsion for more than a decade, but are still a 'novel' propulsive unit compared to the conventional propeller on a shaft. In order to be a real competitor to conventional propulsion, both the total vessel efficiency and the propulsive efficiency have to be increased.

One solution is to use the pod in a contra-rotating concept. Another is to put a pod unit behind a conventional main propeller (Contra-rotating Pod, CRP). A second more promising solution (from an efficiency point of view) is to design a 'true' contra-rotating pod unit having two propellers close together either pushing or pulling (Integrated Contra-rotating Pod, ICP).

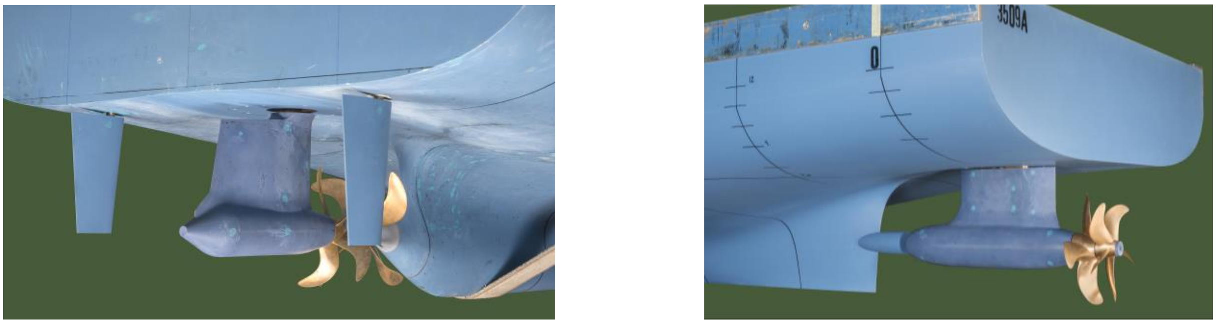


Figure 18: CRP (Left), ICP (Right)

Within STREAMLINE the hydrodynamic performance of propulsive systems, based on contra-rotating propellers and podded propellers, has been analysed through computational modelling. This computational analysis has been performed by means of the hybrid RANSE/BEM model developed by CNR-INSEAN. The methodology aims at combining the capability of RANSE to describe viscous flows around ship hulls and the capability of inviscid flow BEM models to predict reduced computational effort propeller forces. The Cavitation and ventilation behaviour of podded propulsors in service conditions has also been studied using a computational model developed by CNRS providing an improved knowledge on the interaction of cavitation and ventilation, the assessment of ventilation risks in the design phase has been improved.

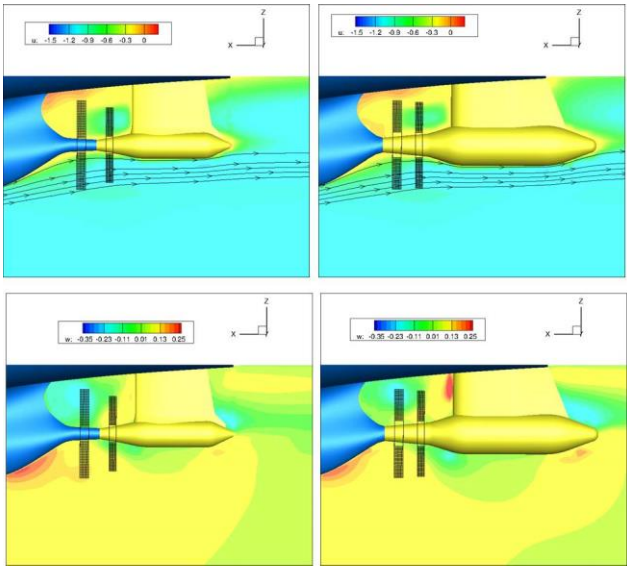


Figure 19:

Through computational modelling and scale model testing, the savings for the CRP and the ICP have been considerable, compared to the reference ship used. The predicted power for the CRP is 13.5% lower than the reference ship, and the corresponding figure for the ICP is 11%. The actual power figures are shown below:

Ship	Displacement [m^3]	Pe [MW] at Vs=20kn	Pd [MW] at Vs=20kn	Comparison of Pd
Original twin-skeg	22980	8.204	11.355	1.000
Streamline CRP	22918	7.754	9.823	0.865
Streamline ICP	22924	7.689	10.110	0.890

Due to these results, throughout the third period, the ICP and CRP concepts were further developed. The reduction in power consumption compared to the previous ICP was 1% and compared to the reference RoRo ship it is in the order of 12%.

The manoeuvre simulations for the CRP also showed that it is possible to control the ship in all weather conditions tested when running in normal conditions, i.e. both propellers running and pod used for steering. The conditions tested covered wind velocities up to 22.6 m/s mean wind and significant wave heights up to 5.6 m. With one propeller stopped, it was demonstrated that it is still possible to control the ship in weather conditions up to Bft8, only using the pod.

3.6.1. Operational Analysis

With a conventional propeller and pod working together, they offer an improved propulsive efficiency, enhanced manoeuvrability, redundancy and flexibility with respect to the changing operating conditions. Both CRP and ICP will be more expensive and complicated in installation and operation.

A single propulsion unit cannot offer the same level of redundancy as the combination of pod and propeller though the manoeuvrability and flexibility will be similar. In the short term, CRP is considered to be much more realistic and practicable, cost effective and more reliable than ICP. However, in the long term, ICP may become cost effective when it gains popularity and becomes part of mainstream technology.

3.6.2. Cost-Benefit Analysis

Cost benefit analysis considering a twin screw reference ship indicates that CRP is economically superior compared to that of the conventional propulsion system, whereas the ICP is economically inferior compared to that of the conventional propulsion system.

3.7. WP3 Advanced CFD Tools

The tools developed within STREAMLINE have been used throughout the project and have been an integral part in the development of the operational technologies. STREAMLINE has shown that CFD tools have the capability to be used as design tools within industry, with a reduction in computational effort and the operator skill level required.

With these new CFD capabilities designers are now able to search for the limits in propeller design. The tools developed within the project are being used today in commercial projects by the STREAMLINE partners.

The following codes were used throughout WP3:

FreSCo+

The finite-volume simulation procedure FreSCo+ has been enhanced to address the specific aspects of advanced propulsion units and their hydrodynamic interplay with the hull as well as (in)flow manipulating devices. Extensions implemented and applied refer to a conservative overset-grid-coupling technology for unstructured moving/deformable grids. The enhancements have been demonstrated to provide the required flexibility and predictive accuracy to investigate problems featuring complex dynamics, e.g. cycloidal/biomechanical propellers or propeller/rudder-interaction. Due to the complex relative motion and dynamics of advanced propulsion units working in behind conditions, the parallel efficiency suffers a from static parallel environment. Accordingly, attention has also been given to dynamic load balancing aspects to improve the speed-up of the implementation which is a major aspect of the industrial usability. Moreover, local grid refinement strategies and vortex supporting techniques have been included under the aegis of STREAMLINE. Grid-refinement criteria have been formulated in accord with an adjoint-based optimisation approach to secure that the actual simulation goal is supported by the grid-refinement process. All aspects have been harmonised with important existing features, e.g. RANS/BEM coupling, gradient-based optimisation, 6 DOF and seaway models etc.

ISIS-CFD

A research code to simulate fully unstructured viscous flows devoted to ship hydrodynamics has been developed. The main results have been the validation of the existing potential capabilities of the code though the various industrial cases proposed in various WP at both model and full scale. STREAMLINE has demonstrated the capability to compute very complex geometries with the propeller in waves through the sliding grid technique from a unique hexahedral unstructured grid and 6 D.o.F (Degrees of Freedom) resolution. This provides an optimum use of grid points and CPU with automatic grid refinement, with load balancing suitable for free-surface capturing, cavitation modelling and other physical based criteria. This has demonstrated a reduced CPU time from a simplified propeller model (BEM model, AD model) and quasi-static approach.

PRO-INS

A Boundary Element Method solver for the hydrodynamic analysis of marine propulsion systems has been developed. This solver includes general interfaces to be coupled with ship viscous-flow solvers operating in hybrid RANS/BEM mode, and with numerical optimisation models to perform shape optimisation studies. The solver can be applied to analyse various types of marine propulsors: fixed-pitch, variable-pitch propellers, ducted propellers, podded propellers.

Chi-Navis

A finite-volume viscous-flow solver based on RANS, DES, LES solutions of the unsteady Navier-Stokes equations. Solver features include: dynamic overlapping grids, level-set free surface model, library of turbulence models, 'body-force' propeller models, multi-body 6 DOF dynamics; multi-paradigm parallelisation. This provides very accurate viscous flow predictions, describing marine vehicles in arbitrary motions. Overlapping grids allow the building of high-quality computational grids at reduced effort; DES and LES allow the description of complex turbulent and vortical structures; propellers can be explicitly solved or modelled via hybrid RANSE/BEM scheme.

Kurgan

A hydroacoustic solver based on the numerical solution of the Ffowcs-Williams and Hawkings equations. This solver is based on a Boundary Element Method generalised to include volume integral contributions. The solver allows the analysis of propagation and scattering of hydrodynamic noise sources on marine vehicles including the effects of the propulsion system. The methodology provides a unique approach to detect broadband noise sources associated to flow turbulence and vortical structures. Interfaces with CFD solvers based on RANS and DES/LES have been developed.

HyPPO

A computational platform for general purpose numerical optimization problems. The platform includes a variety of computational schemes for single-objective or multi-objective optimization, robust optimization, and local as well as global search algorithms. This numerical optimisation platform is very general. Ship performance optimisation can be studied as a shape optimisation problem through new techniques. These numerical optimisation models can be easily interfaced with CFD solvers like "Chi-Navis" and "PRO-INS".

3.8. WP31 Development of Fixed-grid/Rotating-grid Coupling

The development of CFD tools to simulate the propulsor action behind a ship hull, and interaction of these objects. This work package was split into three CFD methods:

- Task 31.1 - Mesh coupling using a sliding grid approach (CNRS, MARIN)
- Task 31.2 - Mesh coupling using overlapping grids (TUHH, HSVA)
- Task 31.3 - Comparisons of various coupling strategies and error (CNRS, MARIN, HSVA, TUHH)

Sliding grid capability in ReFRESCO and ISIS-CFD has been developed. This will provide an extension to the existing software whereby it may be implemented as a design tool to provide a more accurate result in propeller modelling for propellers behind stationary ships or stators.

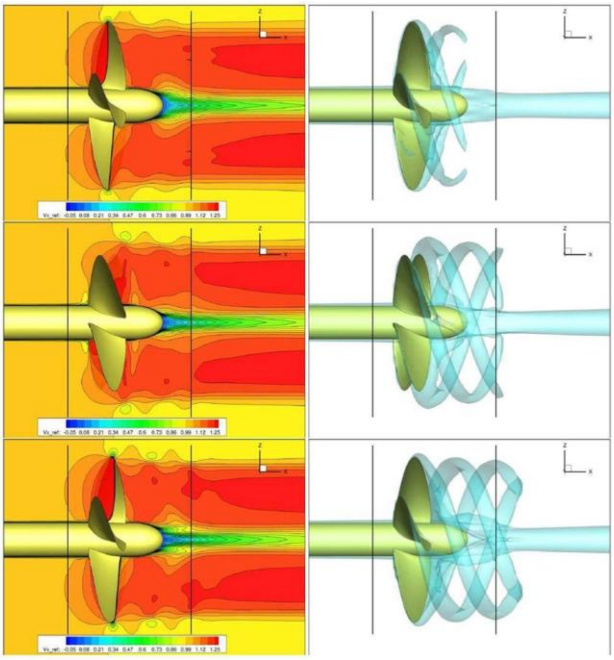


Figure 20: Propeller results using sliding interfaces (from top to bottom) Coarse, medium, fine grid

With the development and implementation of the overlap grid feature in FreSCO+, this provides the capability of simulating objects moving against each other in domains made of multiple grids.

3.9. WP 32 Grid Adaption

The work package covers the development in automatic grid adaption during the CFD computation to simulate flow details such air suction, cavitation, pressure fluctuations, erosion or the footprint of vortex generators, and the interaction of these conditions on different thrusters or propulsors.

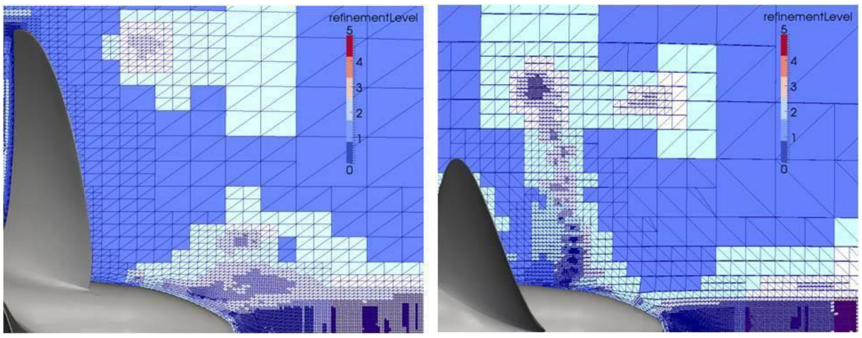


Figure 21: Numerical grid in the wake of the propeller

STREAMLINE has demonstrated an improved grid refinement technology in ReFRESCO, Fresco+, ISIS-CFD, and OpenFOAM software, allowing for a higher grid resolution locally in highly transient flows, this will be effective for large scale parallel computations, and thus improved predictive capability

Compressible viscous flow code with cavitation modelling capability has been improved; this provides the most complete computational model of cavitating flow phenomena developed to date. It also allows for the study into the effect of vapour compressibility in the collapse of the cavity, and the acoustic effects on the near and far field.

3.10. WP33 Prediction of cavitation

The work package covers the development of state-of-the-art cavitation modelling, and the investigation of CFD methods to define a direct characterization of pressure fluctuations and its harmful consequences on marine propulsion systems in terms of erosion risk for propellers and rudders.

Cavitation modelling capability in ReFRESCO and ISIC-CFD has been developed, providing the ability to predict cavitation.

Propeller-induced pressure fluctuations and radiated noise have been investigated by the novel Ffowcs-Williams and Hawkings methodology implemented into the Kurgan code and by a Kirchhoff-Helmholtz methodology implemented into the Excalibur code.

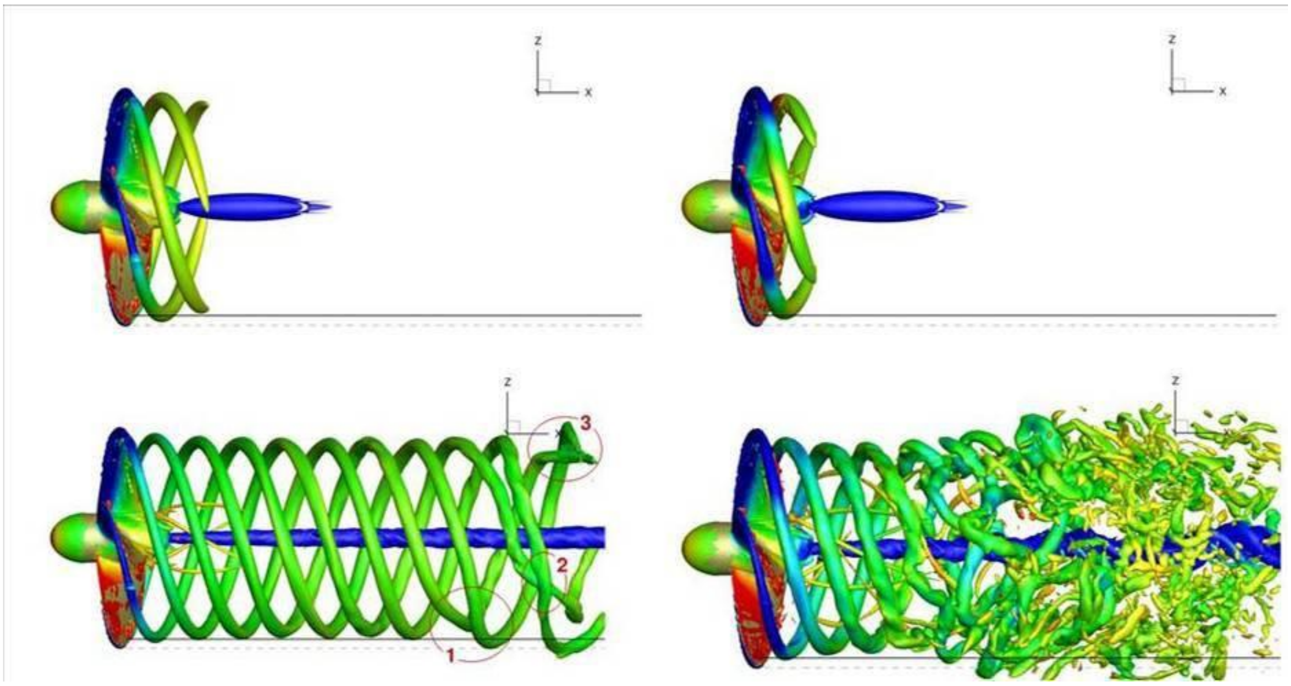


Figure 22: Vorticity distribution in a propeller slipstream evaluated by RANSE (top) and by DES (bottom)

The following software codes were used throughout WP33:

- ISIS-CFD
- ReFRESCO
- PRO-INS
- Chi-Navis
- Kurgan
- Excalibur
- OpenFOAM

3.11. WP34 RANS / BEM Coupled Method

The work package covers the development of efficient RANS / BEM coupling to provide a cost effective approach to investigating hull-propeller interaction and to predict self-propulsion conditions with sufficient accuracy.

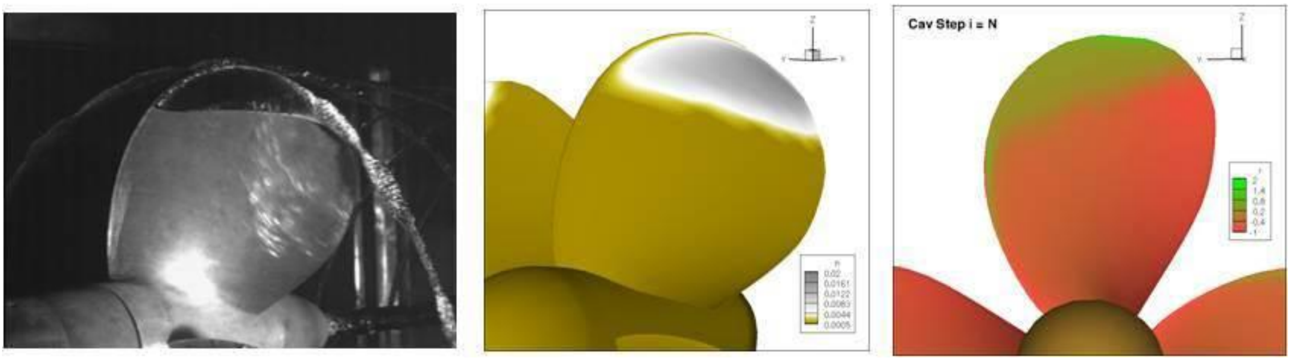


Figure 23: Cavitating flow modelling by BEM

A RANS-BEM coupling software code has been developed, providing fast computations of resistance and propulsion characteristics of hull-propeller combination. The implementation and improvement of the RANS / BEN interface has also been developed, providing an improved simulation procedure using the newly developed RANS-BEM coupling software code.

The following software codes were used throughout WP34:

- ISIS-CFD, Chi-Navis, Parnassos, FRESCO+ (RANSE)
- PRO-INS, QCM, PROCAL (BEM)

3.12. WP35 Design Optimisation

The work package covers the development and assessment of numerical optimisation techniques and automated design procedures, by the improvement of existing numerical optimisation tools. It also includes the revision and update of design procedures to increase the impact of simulation tools and technologies.

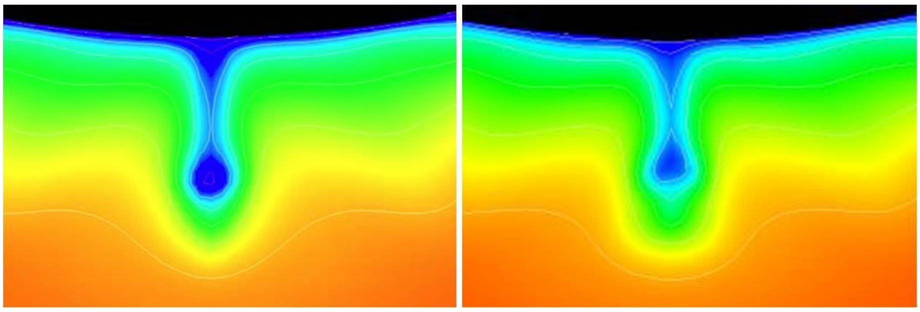


Figure 24: Original (left) and optimised (right) wake field

The software code for the optimisation of the strategy for ship-propeller interaction has been developed. This provided the optimisation of the aft bodies of ships, taking into account the propeller-hull interaction propellers.

The software code for 'Free Form Deformation Technique' has been developed. This provides an optimisation process that reduces the required use of licensed third party software, reducing the required user interaction.

PRO-INS and HyPPO codes were used throughout WP35.

4. Use and Dissemination of Foreground

4.1. Section A (Public)

Within Annex I of the description of work, the dissemination plan was as follows:

- **Press campaign**: a high-profile European press campaign will be set-up in year 4 to communicate to the European citizens at large the expected impact of the STREAMLINE technologies on future marine transport.
- **STREAMLINE public website**: A public website will be set-up to present the main benefits from STREAMLINE in terms of:
  - Impact for the citizen regarding noise and emissions in coastal and inland waterway regions.
  - Technical and industrial achievements.
  - Return of investment, i.e. demonstrating the importance of research spending at European level
- **STREAMLINE Communication materials** (flyers, brochures, etc.) For different target public levels from the general public (focusing on environmental issues) and for the marine stakeholders (focusing on environmental benefits and cost saving) and the scientific community (focusing on innovative technologies).
- **Scientific publications and presentations in key journals and marine conferences**. In particular, the following conferences and journals are targeted:
  - Royal Institute of Naval Architects (RINA) events & conferences
  - Schiffbautechnische Gesellschaft (The German Society for Maritime Technology) - Annual and bi-annual Meetings / Lecture Days on recent advances in both hydrodynamic CFD and propulsion.
  - NuTTS - Numerical Towing Tank Symposium - Annual conference on CFD in hydrodynamics
  - ONR - Office of Naval Research – Symposium on naval hydrodynamics
  - The Symposium on Practical Design of Ships and Other Floating Structures

- ECCOMAS - European Community on Computational Methods in Applied Sciences
- Journal of Fluids Engineering
- Journal of Ship Research
- ASME (American society of Mechanical engineering) Journals
- International Symposium on Cavitation

- **CFD knowledge transfer** – Workshops will be held to ensure the transfer of knowledge on new CFD codes and best practice methodologies to all members of the European Maritime research community
- **University training and PhD courses** to be delivered by the universities involved in STREAMLINE: CHALMERS, CNRS, TUHH and UNEW
- **STREAMLINE output workshop for the marine industry**: In year 4, STREAMLINE will organise a dedicated technical workshop to present the main project results to the marine industry and academia. This workshop should open discussions and further collaborations to address the next steps, mostly how to bring the technology to a higher TRL level and to further improve the results from the lessons learnt in the project. A key aspect will be communicating the results of the novel propulsion concepts and their operational aspects analysis to the wider ship owner/operator community.
- **Participation to other workshops**: STREAMLINE will participate in workshop organised by other organisations when relevant to the STREAMLINE dissemination policy. Envisaged participations include:
- **T-POD conference**, (which UNEW regularly organise every 2/3 years) as platform to disseminate project output.

4.1.1. STREAMLINE Public Website

The STREAMLINE Public website was set up and became live during M6 of the project.

The public website holds information pertaining to the project (short presentation, information on the partners), as well as information on STREAMLINE public events, publications and public deliverables.

Figure 25: Public Website Home Page

The STREAMLINE public website is at the following address: http://www.streamline-project.eu/

Through the public website STREAMLINE could be contacted via the online form, or directly with the project office: Streamline@eurtd.com

4.1.2. STREAMLINE Dissemination Materials

Figure 26: Streamline Brochures for TRA12

In March 2013, brochures were produced for STREAMLINE and were distributed during the dedicated STREAMLINE session at the TRA12 conference. The conference was held in Athens during 25th April 2012.

During the final period, the STREAMLINE project produced a banner that may be used during dissemination events, and a dissemination video which encapsulates the objectives and results of the project, this can be viewed at the following link:

https://www.youtube.com/watch?v=J2AsGFTBhgg

Figure 27: STREAMLINE Banner

4.1.3. List of Scientific (Peer Viewed) publications

NO.	Title	Main Author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (if available)	Is/Will open access provided to this publication ?
1	Hydrodynamic development of Inclined Keel Hull - resistance	Kwang-Cheol Seo	Journal of Ocean Engineering	N/A	Elsevier	UK	2012	V47, pp 7-18	N/A	www.elsevier.com/locate/oceaneng
2	Hydrodynamic Development of inclined Keel Hull Propulsion	Kwang-Cheol Seo	Journal of Ocean Engineering	N/A	Elsevier	UK	2013	V63, pp 90-95	N/A	www.elsevier.com/locate/oceaneng
3	Sub-cycling strategies for maritime two-phase flows.	M. Manzke	Notes on Numerical Fluid Mechanics	N/A	Springer	Germany	2012	Vol. 120, pp. 237-251	N/A	www.elsevier.com/locate/oceaneng

4.1.4. List of Dissemination Activities

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
1	Conference	CHALMERS	Large Area Propellers	15 – 17th June 2011	SMP'11	Scientific / Academic / Industry	92	Europe, Japan, Tasmania, Korea, Taiwan, USA, China
2	Conference	MARIN	Adaptive Mesh Refinement in MARIN's Viscous Flow Solver Refresco: Implementation and Application to Steady Flow	28th – 30th September 2011	IV International Conference on Computational Methods in Marine Engineering MARINE 2011	Scientific / Academic / Industry	100	Europe, USA, Japan, Republic of Korea, China
3	Conference	CHALMERS	A Mesh Adaptive Compressible Euler Model for the Simulation of Cavitating Flow	28th – 30th September 2011	IV International Conference on Computational Methods in Marine Engineering	Scientific / Academic / Industry	100	Europe, USA, Japan, Republic of Korea, China

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
					MARINE 2011			
	Conference	CNR-INSEAN	Numerical Study of Marine Propellers by an unsteady hybrid RANSE-BEM Approach	28th – 30th September 2011	IV International Conference on Computational Methods in Marine Engineering MARINE 2011	Scientific / Academic / Industry	100	Europe, USA, Japan, Republic of Korea, China
4	Conference	TUHH	RANS Simulations Using Overset Meshes	28th – 30th September 2011	IV International Conference on Computational Methods in Marine Engineering MARINE 2011	Scientific / Academic / Industry	100	Europe, USA, Japan, Republic of Korea, China
5	Conference	TUHH	Goal-oriented mesh adaptations for wake-field predictions	28th – 30th September 2011	IV International Conference on Computational Methods in Marine Engineering MARINE 2011	Scientific / Academic / Industry	100	Europe, Us, Asia
6	Publication of Article	CNR-INSEAN	Conformal FFD for the Optimisation of Complex Geometries	July 2011	Shipping Technology Research	Scientific / Academic / Industry		

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
7	Conference	MARIN	Choosing proper object functions in CFD-based hull-form optimization	16th – 18th April 2012	COMPIT 2012	Scientific / Academic / Industry	95	Europe, Brazil, Canada, Malaysia, USA, South Korea
8	Conference	UNEW	Validation of the Inclined Keel application to a Container Vessel	11th – 14th June 2012	IMDC 2012	Scientific / Academic / Industry		
9	Conference	MARIN	Object Functions for Optimizing a Ship's Aft Body	16th – 18th April 2012	COMPIT 2012	Scientific / Academic / Industry	95	Europe, Brazil, Canada, Malaysia, USA, South Korea
10	Conference	RRPE	STREAMLINE TRA 2012 Session	23rd – 26th April 2012	TRA 2012	Scientific / Academic / Industry		
11	Conference	TUHH	Prediction of Roll-	1 – 6th July	31 International Conference on	Scientific /	1500	Europe, US,

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
			Damping using viscous flow solvers	2012	Ocean Offshore and Artic Engineering 2012	Academic / Industry		Asia
12	Conference	MARIN	Analysis of scale effects in ship powering performance using a hybrid RANS-BEM approach	26th – 31st August 2012	29th Symposium on Naval Hydrodynamics	Scientific / Academic / Industry		
13	Conference	TUHH	An Efficient Procedure to Simulate Ship Propulsion in Regular Waves.	30 Aug. 2012	STG Symposium on Simulation of Ships in Seaways	Scientific / Academic / Industry	60	Europe
14	Conference	TUHH	Analyses of Coupled Floating Bodies in Seaway	25th – 27th September 2012	II International Conference on Violent Flows, 2012	Scientific / Academic / Industry	100	Europe, US, Asia
15	Conference	MARIN	Measurement techniques for pods – use of high speed	1st – 6th July 2012	OMAE 2012	Scientific / Academic / Industry	988	38 Countries

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
			footage from WP23					
16	Conference	TUHH	Prediction of Roll-Damping using viscous flow solvers	1 – 6th July 2012	31 International Conference on Ocean Offshore and Artic Engineering 2012	Scientific / Academic / Industry	1500	Europe, US, Asia
17	Publication of Article	RRPE	Rolls-Royce Leads €11m EU Research Programme on Propulsion.	Issue 18 – June 2013	"In Depth" magazine	Scientific / Academic / Industry		Europe
18	Conference	CNRS	A comparison between full RANSE and coupled RANSE-BEM approaches in ship propulsion performance predictions.	9th – 14th June 2013	OMAE 2013	Scientific / Academic / Industry	1244	International, 44 Countries
19	Conference	MARIN	Experimental investigation of the effect of waves and	5th – 7th May 2013	SMP'13	Scientific / Academic / Industry	100	Europe, Japan, Tasmania,

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
			ventilation in depressurised conditions on a POD-propeller of a cruise liner model					Korea, Taiwan, USA, China
20	Conference	TUHH	Multi-Body Hydrodynamics for Offshore Applications using Advanced Viscous Flow Simulation Techniques.	21-22 May 2013	I International Conference on Maritime Energy, COME 2013	Scientific / Academic / Industry	150	Europe, Us, Asia
21	Conference	CNRS	Ship Propulsion Prediction with a Coupled RANSE-BEM Approach	29th – 31st May 2013	ECCOMAS Conference 2013	Scientific / Academic / Industry		International
22	Conference	TUHH	Parallel Performance of Overset Grids Algorithm using Load Balancing.	29 – 31st May 2013	V International Conference on Computational Methods in Marine Engineering	Scientific / Academic / Industry	200	Europe, US, Asia

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
					MARINE 2013			
23	Conference	TUHH	Parallel Performance of Overset Grids Algorithm using Load Balancing.	29 – 31st May 2013	V International Conference on Computational Methods in Marine Engineering MARINE 2013	Scientific / Academic / Industry	200	Europe, US, Asia
24	Publication of Article	RRPE	STREAMLINE	January 2013	Naval Architect	Scientific / Academic / Industry	N/A	Europe
25	Conference	DST	Research and the Inland Waterway Sector	April 2013	ECMAR General Assembly 2013	Management of ECMAR council	7	Europe
26	Conference	MARIN	Optimisation of a chemical tanker and propeller with CFD	29th – 31st May 2013	MARINE Conference 2013	Scientific / Academic / Industry	138	Europe, USA, Japan, Republic of Korea, China, Russian

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
								Federation, Australia, Japan, Faroe Islands, Singapore,
27	Publication of Article	RRPE	Step-change in efficiency the focus of propulsion research	Issue 18 – June 2013	"In Depth" magazine	Scientific / Academic / Industry	N/A	
28	Conference	CHALMERS	Towards Simulation Based Cavitation Erosion Risk Assessment	19th June 2013	STG-Colloquium	Scientific / Academic / Industry		Europe
29	Conference	CNR-INSEAN	Optimisation of a chemical tanker with free-surface viscous flow computations	20th – 25th October 2013	PRADS 2013	Scientific / Academic / Industry		Europe / Korea
30	Publication of Article	SSPA	Large Area Propeller	Issue 57 - 2013	Magazine 'Highlights'	Scientific / Academic / Industry	N/A	Europe

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
31	Conference	MARIN	Adaptive mesh refinement in MARIN's viscous flow solver ReFRESCO: refinement in the near-wall region, implementation and verification	2nd – 4th September 2013	NuTTS'13	Scientific / Academic / Industry	45	Europe, Japan, Canada
32	Publication of Article	MARIN	CFD for integrated calm water ship-propeller design	July / August 2013	Naval Architect	Scientific / Academic / Industry	N/A	
33	Conference	CHALMERS	Simulation of the Unsteady Propeller Blade Loads using OpenFOAM	2nd – 4th September 2013	NuTTS'13	Scientific / Academic / Industry	45	Europe, Japan, Canada
34	Conference	MARIN	Systematic propeller optimization using an unsteady Boundary-Element Method	20th – 25th October 2013	PRADS 2013	Scientific / Academic / Industry		Europe / Korea
35	Dissemination	CNR-	CNR-INSEAN activity	Sept 2013	CNR-INSEAN	Scientific /	N/A	International

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
	Material	INSEAN	within STREAMLINE		Brochures	Academic / Industry		
36	Conference	CNRS	Dynamic Behaviour of the Loads of Podded Propellers in Waves: Experimental and Numerical Simulations	8th – 13th June 2014	OMAE 2014	Scientific / Academic / Industry	N/A	It is expected that there will be over 1400 attendees from 40 countries.
37	Dissemination Material	ARTTIC	Production of STREAMLINE Banner	Nov 2014	STREAMLINE	Scientific / Academic / Industry	N/A	International
38	Conference	CNR-INSEAN	Comparative analysis of the hydrodynamic performance of conventional and twisted rudders using a hybrid RANSE/BEM model	15th – 20th June 2014	ISOPE – 2014	Scientific / Academic / Industry	Excepted 1000	International
39	Conference	CNR-INSEAN	On the effect of vortex generators on the flow	15th – 20th June 2014	ISOPE – 2014	Scientific / Academic /	Excepted 1000	International

NO.	Type of Activities	Main Leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
			field around a tanker scale model: A Stereo-PIV investigation			Industry		
40	Conference	CNR-INSEAN	Computational analysis of contra-rotating podded propulsors using a hybrid RANSE/BEM model	19th – 24th October 2014	ICHD 2014	Scientific / Academic / Industry	N/A	33 Countries Expected
41	Dissemination Material	ARTTIC	STREAMLINE Dissemination Video	Feb 2014	STREAMLINE	Scientific / Academic / Industry	N/A	
42	Public Website	ARTTIC	STREAMLINE Public Website	August 2010	STREAMLINE	N/A	N/A	N/A

4.1.5. University training and PhD courses

The contribution made by UNEW to the "Inclined keel Hull" concept in the Large Area Propeller WP was the outcome of a PhD project by the following refs:

"Seo, K.C.,2010. Application of Inclined Keel to Large Commercial Ships Ph.D. Thesis. Newcastle University, UK"

During the course of the STREAMLINE project the Inclined Keel Hull concept and project activities, which have involved further development and experimental verification of the concept, have provided stimulus to numerous undergraduate (BSc) and Postgraduate (MSc) student final year projects and thesis in the School of Marine Science and Technology of Newcastle University.

One licentiate thesis by CHALMERS university has been published:

http://publications.lib.chalmers.se/publication/188724-large-area-propellers.

CHALMERS also using the water jet experiments conducted within STREAMLINE in a PhD work that will be presented in October. Furthermore, the STREAMLINE tanker has been used in one MSc thesis project, with some of the published work being used as teaching material in MSc in Naval Architecture courses.

4.1.6. STREAMLINE Final Work Shop

During the final period, the STREAMLINE project held its final dissemination event in Malta. Further details on the event can be found at the following link:

http://www.eurtd.com/streamline/2014/final-event/

The event was attended by the STREAMLINE consortium, and several members of the European Maritime Industry who were outside of the project:

NAME	ORGANISATION
Ivan Schroonyen	Ulstein Design & Solutions
Stephen Ciappara	London Offshore Consultants
John Ross	Malta Yacht Surveys
Vasileios Tsarsitalidis	NTUA

4.2. Section B (Confidential or Public: confidential information must be marked clearly)

Part B1

4.2.1. List of Applications for Patents, Trademarks, Registered designs

Type of IP Rights	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject of Application	Applicant(s) (as on application
	YES		GB1105554.8	(D22.2) Preliminary Concept Study – High efficiency water jet at low speed. Concept for variable area waterjet intake. Optimised water jet inlet geometry with porous lip.	Rolls-Royce (RRAB)
	YES		GB1105555.5	(D22.2) Preliminary Concept Study – High efficiency water jet at low speed. Concept for variable area waterjet intake. Water jet employing flow control using additional jets.	Rolls-Royce (RRAB)
	YES		GB1105556.3	(D22.2)	Rolls-Royce

Type of IP Rights	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject of Application	Applicant(s) (as on application
				Preliminary Concept Study – High efficiency water jet at low speed. Concept for variable area waterjet intake. Water jet intake with inflatable surface to create area change	(RRAB)
	YES		GB1105558.9	(D22.2) Preliminary Concept Study – High efficiency water jet at low speed. Concept for variable area waterjet intake. Water jet intake with opening doors.	Rolls-Royce (RRAB)

4.2.2. List of Exploitable Foreground

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
Application of CFD codes	(D11.6) Results produced within WP11 A large number of systematic propulsion computations for three hulls and three propellers at different positions both at model and full scale. Evaluation of a POD alternative. The code is only available through commercial licensing.	NO	N/A	Application of Large Area Propeller	Offshore Commercial shipping	N/A	Code is only available through commercial Results obtained upon request	CNRS
Advancement in the Large Area Propeller technology	(WP11) Results generated within STREAMLINE on the advancement of the LAP technology have allowed	YES	N/A	Large Area Propeller	Offshore commercial shipping	Development within the LEANShip project to demonstrat	N/A	Rolls Royce

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	Rolls Royce to further develop this technology beyond STREAMLINE					e the Large Area Propeller technology on a series vessel together with European ship operator, yard and research organisation. Development of a demonstration vessel		

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						by Rolls Royce.		
Advancement in knowledge.	(D12.3) WSP design and propulsion concept	YES	N/A	Ship Propulsion	Propulsion	No date at this time, seeking partnership and investor	Patent held in NL	Walvisstaart BV
Advancement in knowledge.	(D12.6) WSP blade control software: Ship construction/ propulsion	YES	N/A	Ship Propulsion	Propulsion	No date at this time, seeking partnership and investor	Patent held in NL	Walvisstaart BV
Advancement in knowledge.	(D12.6) Body lines/ship construction/ propulsion	YES	N/A	Body Lines	Propulsion	No date at this time, seeking partnership and investor	Patent held in NL	Walvisstaart BV
Assessment of optimised unconventional	(D12.10) Work carried out in	NO – Results available	N/A	Application		Available in the	Code is only available through	CNRS and Ecole Centrale de

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
propeller in operating conditions	WP12 consisting of CFD simulations with ISIS-CFD in full RANS for the WSP system. This code is available through commercial licensing	upon request				commercial version FINE™/Marine	commercial Results obtained upon request	Nantes
Advancement in knowledge.	(D13.2) Test results within other research projects Dutch research project PELS. Knowledge on artificially ventilated propellers. Methods to conduct and analyses of open water tests.	YES	N/A	Knowledge might be used to interpret findings within STREAMLINE	Model Testing	N/A	Names of the licensees/report: 14972-7-DT Partially Ventilated Open Water Test Date of allocation: 8/2003 Type of licence: Senter/	MARIN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
							novem fundet project	
Advancement in knowledge. Application CFD Codes	(D13.3) Results produced within WP13 on distributed thrust concept, this work has consisted of simulation of the prediction of ventilation risk about ducted and computation of a distributed propulsion solution	NO	N/A	Application CFD Codes	Ship Propulsion Design	Available in the commercial version FINE™/Marine	Code is only available through commercial Results obtained upon request	CNRS
Advancement in knowledge. Model for IWW costs	(D13.4) Cost model to determine transport related costs of IWW shipping	NO	N/A	Model for IWW costs	Inland water way shipping	N/A	Restricted for commercial projects of STREAMLINE partners for costs of	DST

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
							inland navigating shipping	
Advancement in knowledge, commercial exploitation of R&D Results	(D21.2) Expert Knowledge in the simulation and analysis of propeller / rudder configurations Background knowledge required to use Foreground is the RANS code FreSCo+ and the BEN code QCM	YES	31.12.2023 house code. Not for distribution	Consulting services for customers.	Maritime Fluid Dynamics in Research and Consulting	The expert knowledge gained is used in national and EU research projects (e.g EU FP7 project grip, German national project NoWelle)	N/A	HSVA and TUHH
Advancement in knowledge, commercial exploitation of R&D Results	(D21.3) Propeller-inflow improving devices. Expert knowledge in the	NO	N/A	N/A	Maritime Fluid Dynamics in Research	N/A	N/A	HSVA and TUHH

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
	design, simulation and analysis of inflow improving devices				and Consulting			
Advancement in knowledge, commercial exploitation of R&D Results	(D21.3) Propeller-inflow improving devices. Expert knowledge in the design, simulation and analysis of inflow improving devices. Background required to use the Foreground is the RANS code FreSCo+ and the inviscid BEM code QCM	YES	31.12.2023	Consulting services for customers.	Maritime Fluid Dynamics in Research and Consulting	The foreground knowledge is applied in ongoing commercial and research projects (e.g. FP7 project GRIP).	N/A	HSVA and TUHH
Advancement in knowledge, commercial exploitation of	(D21.3) A detailed study of the design of vortex generators for a tanker in	NO	N/A	Software and CFD packages	Ship Design and Ship Retrofit	N/A	N/A	TUHH

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
R&D Results	full scale has been carried out. Results show the potential of modern CFD methods as design tools. Results have been produced using FreSCo+. In general, most modern CFD packages with grid adaptation capabilities are suitable.							
Advancement in knowledge, commercial exploitation of R&D Results	(D21.3) The work consists in the simulation of the hull and device/propeller interaction. The flow solver is the ISIS-CFD code and the propeller is modelled with the help of the CNR-INSEAN PFC-	NO	N/A	Application of software	Ship Design and Ship Retrofit	Available in the commercial version FINE^{TM}/Marine	Code is only available through commercial Results obtained upon request	CNRS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	1.3 BEM solver. The code is only available through commercial licensing.							
Software and Knowledge	(D21.4) Computational algorithms and software for the parameterization of propeller blade geometry for shape optimization problems. Improved procedures for propeller design by the BEM method PROCAL. Foreground is result of activity by MARIN that did not require direct contributions from other project partners.	YES	N/A	Exploitation of foreground involves background knowledge and tools on theoretical models and numerical algorithms for the hydrodynamic analysis and the numerical optimization of marine propellers.	Ship Design and Ship Retrofit	Results of developments achieved during the project will be the subject of forthcoming manuscripts submitted to scientific journals and conferences.	All developed software is property of MARIN	MARIN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
Computational algorithms and software	(D21.4) Computational algorithms to adapt general-purpose numerical optimization models to analysis of marine propellers and related coding into software. Computational algorithms and software for the parametrisation of propeller blade geometry for shape optimization problems. Knowledge on computationally-efficient techniques to combine propeller hydrodynamics models and shape optimization models	YES	N/A	Exploitation of foreground involves background knowledge and tools on theoretical models and numerical algorithms for the hydrodynamic analysis and the numerical optimization of marine propellers.	Ship Design and Ship Retrofit	Results of developments achieved during the project will be the subject of forthcoming manuscripts submitted to scientific journals and conferences. At Delivery submission date, 1 manuscript has been submitted for publication on	PRO-INS is a Registered Trade Mark. All related computational algorithms are property of CNR-INSEAN and commercial licensing is subject to be negotiated by parties	CNR-INSEAN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	Foreground is result of activity by CNR-INSEAN that did not require direct contributions from other project partners.					International Scientific Journal.		
Software, knowledge	(D21.4) Computational algorithms and software to deform geometries Foreground is result of activity by HSVA that did not require direct contributions from other project partners.	YES		Exploitation of foreground involves background knowledge and tools on theoretical models and numerical algorithms for the hydrodynamic analysis and the numerical.	Ship Design and Ship Retrofit	Results of developments achieved during the project will be the subject of forthcoming manuscripts submitted to scientific journals and conferences.	All developed software is property of HSVA	HSVA
Computational models and	(D21.5)	YES		Computational models and	Ship Design and	Results of development	PRO-INS is a Registered	CNR-INSEAN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
Software	Computational algorithms to adapt general-purpose numerical optimization models to analysis of marine propellers and related coding into software. Computational algorithms and software for the parameterisation of propeller blade geometry for shape optimization problems. Knowledge on computationally-efficient techniques to combine propeller hydrodynamics models and shape optimization models Foreground is result of			Software	Ship Retrofit	s achieved during the project will be the subject of forthcoming manuscripts submitted to scientific journals and conferences. At Delivery submission date, 1 manuscript has been submitted for publication on International Scientific	Trade Mark. All related computational algorithms are property of CNR-INSEAN and commercial licensing is subject to be negotiated by parties	

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	activity by CNR-INSEAN that did not require direct contributions from other project partners.					Journal.		
Computational models and software	(D21.5) An extension of computational algorithms to do multi-objective optimisation of ship hull forms. Optimisation models to analyse marine propellers and related coding Computational algorithms and software for parameterisation of propeller blade geometry for shape optimisation. An extension of the knowledge on choosing	YES		Computational models and software	Ship Design and Ship Retrofit	Results of developments achieved during the project will be the subject of forthcoming manuscripts submitted to scientific journals and conferences. At the delivery submission date, 1	Software is the property of MARIN	MARIN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	the proper object functions for the optimisation of ship hull forms and propellers.					manuscripts had been submitted for publication as proceeding for scientific conferences: COMPIT 2012 and MARINE 2013		
Advancement of Knowledge.	(D21.6) Large-eddy simulation, with the FOI in-house software, and the comparison with results obtained with full RANS and RANS / BEM coupling	YES		Application	Ship Design and Ship Retrofit	Results of developments achieved during the project will be the subject of forthcoming manuscripts	Results obtained upon request	FOI

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						submitted to scientific journals and conferences		
Advancement of Knowledge.	(D21.6) CFD simulations with ISIS in full RANS and with a RANS/BEM coupling.	YES	N/A	Application	Ship Design and Ship Retrofit	The 32nd International Conference on Ocean Offshore and Arctic Engineering – OMAE 2013, the V International Conference on Computational Methods in Marine Engineering – MARINE	Code is only available through commercial Results obtained upon request	ECN-CNRS

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
						2013		
Software, knowledge	(D21.6) CFD simulations with ReFRESCO using full RANS simulations for propeller-hull interaction	Software: YES	N/A	Software	Ship Design and Ship Retrofit	N/A	Developed software is the property of MARIN Results obtained upon request	MARIN
Advancement of Knowledge	(D21.7) Large-eddy simulation, with the FOI in-house software, and the comparison with results obtained with full RANS and RANS / BEM coupling	YES	N/A	Application	Ship Design and Ship Retrofit	Results of developments achieved during the project will be the subject of forthcoming manuscripts submitted to scientific journals and	Results obtained upon request	FOI

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						conferences		
Advancement of knowledge	(D21.7) CFD simulations with ISIS in full RANS and with a RANS/BEM coupling.	YES	N/A	Application	Ship Design and Ship Retrofit	N/A	Results obtained upon request	ECN-CNRS
Software, knowledge	(D21.7) CFD simulations with PARNASSOS and PROCAL and RANS/BEM simulation	Software: YES Results available upon request			Ship Design and Ship Retrofit		Developed software is the property of MARIN Results obtained upon request	MARIN
Advancement of Knowledge and Computational algorithms	(D21.7) Implementation of transient RANS/BEM coupling methods. Background required to use RANS model and the	YES	31.12.2023	RANSE code coupled with the BEM code PRO-INS	Maritime Fluid Dynamics in Research and	Full commercial use is foreseen post STREAMLIN	PRO-INS is a registered trade mark	CNR-INSEAN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	BEM code PRO-INS				Consulting	E		
Advancement of knowledge and development of computational algorithms for ship hydrodynamics	(D21.8) Advancement of knowledge and development of computational algorithms for ship hydrodynamics	YES	General terms for EU-FP7 Project applied	Arbitrary RANSE code couple with the BEM code PRO-INS	Maritime Fluid Dynamics in Research and Consulting	Full commercial use is foreseen post STREAMLINE	PRO-INS is a registered trade mark	CNR-INSEAN
Application and analysis of knowledge	(D21.9) The assessment worked based on LES of complete hull-propeller configurations, including flow-noise predictions with a model, of the FWH-type, based on the computed time-resolver flow. Hull pressure fluctuations and unsteady propeller forces were also	YES	N/A	Application of codes and results obtained	Ship Design and Ship Retrofit	N/A	Results obtained upon request	FOI

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	computed and analysed.							
Application and analysis of knowledge	(D21.10) The assessment worked based on LES of complete hull-propeller configurations, including flow-noise predictions with a model, of the FWH-type, based on the computed time-resolver flow. Hull pressure fluctuations and unsteady propeller forces were also computed and analysed.	YES	N/A	Application of codes and results obtained	Ship Design and Ship Retrofit	N/A	Results obtained upon request	FOI
Advancement of knowledge Commercial exploitation of R&D results	(D21.13) Implementation of transient RANS/BEM coupling Background required to use the foreground is the	Yes	31.12.2023 house code/ not for distribution	FreSCo+ code coupled with the inviscid code QCM	Maritime Fluid Dynamics in Research and	The RANS/BEM coupling is fully integrated in the current	N/A	HSVA / TUHH

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	RANS code FreSCo+ and the BEM code QCM Implementation of Direct Modification Free Form Defor- mation (DMFFD) Background required to use the foreground is the RANS code FreSCo+ and the BEM code QCM				Consulting	productive revision of the FreSCo+ code used for research and commercial projects at HSVA.		
General advancement of knowledge on development of computational algorithms and model test procedures for ship hydrodynamics and ship design	(D21.14) New analysis and design tools for hulls, propellers rudders and energy saving devices	YES	General terms for EU-FP7 Projects applied	Ship hydrodynamics and numerical optimization tools	Maritime Fluid Dynamics in Research and Consulting	Knowledge and results have been used as background in two H2020 proposals, one national project proposal and one FP7	Some software is protected	CNR-INSEAN, MARIN, HSVA, Chalmers, TUHH, FOI, CTO

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						MARTEC-II proposal. The work is also be used in other present and future research collaboration with Rolls-Royce and other partners.		
General advancement of knowledge. Commercial exploitation of R&D Results	(D22.3) Waterjet intel design	NO	N/A	Water jet inlets	Water jet Powered Vessels	N/A	N/A	RRAB

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
Advancement in Knowledge	(D22.5) Advancement in Knowledge	YES	N/A	Water jet testing techniques	Water jet Powered Vessels	N/A	N/A	SSPA
Advancement in Knowledge	(D23.1 / D23.3) The resulting new techniques are fully integrated into the current productive version of the FreSCo+ code. It is used in the daily research and consulting work. The use of the software is foreseen in future Horizon 2020 projects as well as national research projects.	YES	N/A	Contra-rotating pod testing technique in towing tank and cavitation tunnel as well as design of contra-rotating propellers	Model testing and design of pods	Further use and or advancement of the technologies developed within STREAMLINE will be dependent upon market development, With the knowledge obtained, SSPA will be able to	N/A	SSPA

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
						provide existing and potential customers with a better indication of the fuel savings which could be achieved by the use of this technology.		
General advancements in knowledge Computational models and Software	(D23.4) Development of the computational algorithms to couple BEM and RANSE models for the analysis of hull/propulsor hydrodynamic interaction	YES	N/A	Computational models and Software	Maritime Fluid Dynamics in Research and Consulting	Results of developments achieved during the project will be the subject of forthcoming	Software PRO-INS, Chi-Navis and related computational algorithms are property of CNR-	CNR-INSEAN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	Implementation of routine to couple BEM and RANSE models into a hybrid viscouse / inviscid flow solver Knowledge on performance of hybrid viscouse / inviscid flow models applied to study hull/propulsion and contra-rotating propulsion systems.					manuscripts submitted to scientific journals and conferences	INSEAN	
General Advancement in Knowledge.	(D23.5) CFD simulations with ISIS-CFD in full RANS and podded propeller	YES	N/A	Application of CFD simulations	Ship Propulsion design	N/A	Code is available through commercial licensing. Results are available on request.	ECN-CNRS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
General Advancement in Knowledge.	(D23.6) All work carried out within WP23	NO		Evaluation of scaling procedures for model tests on podded propulsors	Model testing and scaling of pods	N/A	Information reported is freely accessible	MARIN
General Advancement in Knowledge.	(D31.1) Validations of the sliding grid procedures in ISIS-CFD.	YES	N/A	Application	Maritime Fluid Dynamics in Research and Consulting	Presented at IWSH'2011 in Shanghai, China and at the NuTTS'2011 conference	The code is only available through commercial licensing. Results are available upon request	CNRS
General Advancement in Knowledge	(D31.2) Overset grid coupling techniques within FreSCO+ (Release Cranz), owned by TUHH / HSVA.	YES	N/A	Software	Maritime Fluid Dynamics in Research and	ECCOMAS MARIN 2011. Papers are foreseen and software will be used with	Access subject to bilateral agreement. Access limited to an	TUHH

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
					Consulting	other WPs.	executable form for the duration for the project only.	
General Advancement in Knowledge	(D31.2) Overset grid coupling techniques within FreSCO+ (Release Cranz), owned by TUHH / HSVA.	YES	01/01/2024	Software	Maritime Fluid Dynamics in Research and Consulting	Software will be used within other WPs and also in future research and commercial projects.	Access subject to bilateral agreement. Access limited to an executable form for the duration for the project only.	HSVA
General Advancement in Knowledge	(D31.3) Application and verification of sliding-	NO`	N/A	Application	Maritime Fluid Dynamics	N/A	The code is available through	MARIN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	interface in Re-FRESCO				in Research and Consulting		commercial licensing	
General Advancement in Knowledge	(D31.3) Application and verification of sliding grid procedures in ISIS-CFD	NO	N/A	Application	Maritime Fluid Dynamics in Research and Consulting	Available in the commercial version FINE™/Marine	The code is available through commercial licensing Results obtained upon request	CNRS
General Advancement in Knowledge	(D31.3) Overset grid coupling techniques with FreSCO+	YES	01/01/2024	Software	Maritime Fluid Dynamics in Research and Consulting	ECCOMAS MARINE 2011. Papers are foreseen and software will be used within STREAMLIN	Access subject to bilateral agreement. Access limited to an executable form for the	TUHH, HSVA

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						E The resulting new techniques are fully integrated into the current productive version of the FreSCo+ code. It is used in the daily research and consulting work.	duration for the project only.	
General Advancement in Knowledge	(D32.1) The implementation of an error estimator based on	YES	N/A	Software	Maritime Fluid Dynamics in	N/A	Copyright 2010	CHALMERS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	the jump over the cell faces. The error estimator has been implemented within the OpenFOAM framework.				Research and Consulting		Type of licence: GNU General Public Licence	
General Advancement in Knowledge	(D32.1) Validations of the grid refinement procedure in ISIS CFD.	YES	N/A	Application	Maritime Fluid Dynamics in Research and Consulting	To be presented at ADMOS 2011 in Paris and MARINE 2011 in Lisbon	The code is only available through commercial licensing	CNRS
General Advancement in Knowledge	(D32.1) Grid adaptation capabilities within ReFRESCO, solely owned by MARIN Background required is the basic version of	YES		Software Package	Maritime Fluid Dynamics in Research and Consulting	Software to be used within STREAMLIN E	Access to the code is through commercial licensing (MARIN). MARIN will	MARIN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	ReFRESCO.						perform calculations for partners and deliver results.	
General Advancement in Knowledge Software Package	(D32.1) Grid Adaptation capabilities including error estimation techniques within FreSCo+ (Release Cranz), owned by TUHH. Goal oriented Grid Adaptation indicators using FreSCo+ (Release Cranz) together with Ad-FreSCo+ (Release Cranz), owned by TUHH.	YES	01/01/2024	Software	Maritime Fluid Dynamics in Research and Consulting	Software to be used within STREAMLINE The resulting new techniques are fully integrated into the current productive version of the FreSCo+	Access subject to bilateral agreement. Access limited to an executable form for the duration of the project only.	TUHH, HSVA

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	FreSCo+ (Release Cranz),Ad-FreSCo+ (Release Cranz).					code. It is used in the daily research and consulting work.		
General Advancement in Knowledge Software	The implementation of an error estimator based on the jump over the cell faces. The error estimator has been implemented within the OpenFOAM framework.	NO	N/A	Open Source	Maritime Fluid Dynamics in Research and Consulting	Currently in use in other research projects being conducted.	Access subject to bilateral agreement. Access limited to an executable form for the duration of the project only.	CHALMERS
Advancement of knowledge Commercial	(D32.2) Implementation of dynamic load balancing	YES	31/12/2023	FreSCo+ Code with dynamic parallel load	Maritime Fluid Dynamics	Full commercial application is	N/A	HSVA, TUHH

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
exploitation of R&D results	algorithms into the FreSCo+ code Background required to use the Foreground is the RANS code FreSCo+			balancing	in Research and Consulting	foreseen starting 1/1/2013 The resulting new techniques are fully integrated into the current productive version of the FreSCo+ code. It is used in the daily research and consulting work.		
Advancement of knowledge	(D32.2)	YES	N/A	ISIS-CFD Code with dynamic	Maritime Fluid	Full commercial	N/A	CNRS

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
Commercial exploitation of R&D results	To verify that the a sliding grid capability works together with the existing grid refinement and automatic dynamic load balancing capabilities of the finite-volume flow solver ISIS-CFD Background required to use the Foreground is the RANS code ISIS-CFD			parallel load balancing	Dynamics in Research and Consulting	application started in December 2006 Available in the commercial version FINE^{TM}/Marine		
Advancement of knowledge Commercial exploitation of R&D results	(D32.2) Implementation of dynamic load balancing algorithms into the OpenFOAM software version 2.1.x Background required to use the Foreground is the OpenFOAM software	YES	31/05/2022	Open source software subroutines	Research projects involving Computational Fluid Dynamics	Application in research projects started in 2013	Results available on request. GNU General Public Licence	CHALMERS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	version 2.1.x							
General Advancement in Knowledge	(D32.3) Application and verification of automatic grid adaption in ReFRESCO	YES	N/A	Application	Research projects involving Computational Fluid Dynamics	N/A	Code is available through commercial licensing	MARIN
General Advancement in Knowledge	(D32.3) Validation of the Grid refinement procedures in ISIS-CFD	YES	N/A	Application	Research projects involving Computational Fluid Dynamics	Available in the commercial version FINE^{TM}/Marine	Code is available through commercial licensing	CNRS
General Advancement in Knowledge	(D32.3) Application of automatic grid refinement using CHALMERS OpenFOAM Solver employs OpenFOAM framework	NO	N/A	Open source software subroutines	Research projects involving Computational Fluid Dynamics	ECCOMAS MARINE 2011 in Lisbon. 29th Symposium on Naval Hydrodynami	Results available on request. GNU General	CHALMERS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
Application						cs in Gothenburg Results available on request. GNU General Public Licence	Public Licence	
General Advancement in Knowledge	(D33.1) Information on enhancements and extensions and results of application Implementation is possible in any RANS, DES or LES code	NO	N/A	N/A	Research projects involving Computational Fluid Dynamics	M. Hoekstra: 'Exploratory RANS simulations of partial cavitation and its dynamics', MARINE	The information in the deliverable is freely accessible	MARIN, CNRS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						2011 Conference, Lisbon (2011)		
General Advancement in Knowledge	(D33.2) The development of a CFD solver designed for including compressible effects in cavitating flows. The solver employs the OpenFOAM framework	NO	N/A	Open Source compressible cavitation solver Software	Fundamental research on cavitation dynamics erosion, and noise.	Adaptive compressible simulations were presented at MARINE 2011 in Lisbon. Viscous compressible simulations will be presented at the 29th Symposium on Naval Hydrodynami	Copyright 2010 – 2011 GNU General Public Licence Available upon request	CHALMERS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						cs in Gothenburg 2012. The knowledge and solver technology has formed the basis for one project proposal in H2020 for an ITN on cavitation erosion and in one national research project.		

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
Advancement of Knowledge	(D33.3) Requirements for reliable assessment of cavitation erosion risk in CFD.	NO	N/A	As general knowledge on erosion risk assessment, in particular in application in CFD Codes	CFD Based design of propulsion systems	Tools implementing this knowledge is expected to be implemented in Rolls-Royce design systems by the end of 2015, as an outcome of research collaboration outside STREAMLINE. The knowledge has formed basis for one	N/A	CHALMERS

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
						application in H2020 and an ITN on cavitation erosion.		
Computational models and software	(D33.4) Computational algorithms for the numerical solution of Ffowcs-Williams and Hawkings Equations via direct and porous surface formulations and related coding into software Knowledge on interfacing hydrodynamics by CFD and hydro acoustics by Ffowcs-Williams and Hawkings Equation models Computational algorithms	YES	N/A	Exploitation of foreground involves background knowledge and tools on theoretical models and numerical algorithms for the numerical solution of the Ffowcs-Williams and Hawkings Equations applied to hydro	Ship Design and Ship Retrofit	Results of developments achieved during the project will the subject of fore coming manuscripts submitted to scientific journals and conferences. At Delivery submission date, no finalised	Theoretical models and numerical algorithms describing foreground tools and knowledge are made available through publications as technical reports and open literature.	CNR-INSEAN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	for the numerical solution of hull scattering through a boundary integral equation based on the Ffowcs-Williams and Hawkings Equation for acoustic pressure			acoustics analysis of ships and marine propulsion systems.		manuscripts are listed.		
General Advancement in Knowledge	(D33.5) Application and verification of a coupled CFD/BEM model for radiated noise and hull surface pressures	YES	N/A	Application	Model Testing	N/A	Code is available through commercial licence	MARIN
Computable models and software	(D33.6) Computational algorithms for the numerical solution of Ffowcs-Williams and Hawkings Equations via direct and porous surface formulations and related	YES	N/A	Exploitation of foreground involves background knowledge and tools on theoretical	Ship Propulsion design	Results of development s achieved during the project will the subject of fore coming	Theoretical models and numerical algorithms describing foreground tools and	CNR-INSEAN

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
	coding into software Knowledge on interfacing hydrodynamics by CFD and hydro acoustics by Ffowcs-Williams and Hawkings Equation models Computational algorithms for the numerical solution of hull scattering through a boundary integral equation based on the Ffowcs-Williams and Hawkings Equation for acoustic pressure			models and numerical algorithms for the numerical solution of the Ffowcs-Williams and Hawkings Equations applied to hydro acoustics analysis of ships and marine propulsion systems.		manuscripts submitted to scientific journals and conferences. At Delivery submission date, no finalised manuscripts are listed.	knowledge are made available through publications as technical reports and open literature.	
General Advancement in Knowledge	(D33.7) Development of numerical indicator functions of cavitation erosion.	NO	N/A	Indicator Functions	Design of marine propulsion system	This is expected to be implemented in Rolls-	GNU General Public Licence. Available	CHALMERS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
Software						Royce design systems by the end of 2015, as an outcome of research collaboration outside STREAMLINE. The knowledge has formed basis for one application in H2020 and an ITN on cavitation erosion.	upon request.	
Advancement of knowledge, and commercial	(D34.1) Development, verification and validation of	NO	N/A	Computational algorithms and software	Maritime Fluid Dynamics	Publication on open scientific	N/A	CNR-INSEAN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
exploitation of R&D Results	improved computational algorithms for the analysis of marine screw-based propulsors by a BEM technique Numerical algorithms are implemented into PRO-INS package by CNR-INSEAN				in Research and Consulting	literature.		
Advancement of knowledge, and commercial exploitation of R&D Results	(D34.2) Implementation of transient RABS/BEM coupling. Background required to use the foreground is the RANS code FreSCo+ and the BEM code QCM	YES	31.12.2023 house code / not for distribution	FreSCo+ and the BEM code QCM	Maritime Fluid Dynamics in Research and Consulting	The resulting new techniques are fully integrated into the current productive version of the FreSCo+ code. It is used in the	N/A	HSVA, TUHH

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						daily research and consulting. The use of the techniques is foreseen in future Horizon 2020 projects.		
Advancement and knowledge in computational algorithms	(D34.2) Implementation of transient RANS/BEM coupling methods. Background required to use foreground is the RANS code CHI-NAVIS and the BEM code PRO-INS	YES	31.12.2023	CHI-NAVIS code coupled with the inviscid code PRO_INS	Maritime Fluid Dynamics in Research and Consulting	Full commercial use after the end of the STREAMLINE project	PRO-INS is a registered trade mark of CNR-INSEAN	CNR-INSEAN
Advancement of	(D34.2)	NO	N/A	Software	Maritime	Ship	The code is	CNRS

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
knowledge, and commercial exploitation of R&D Results	Implementation of the coupling of BEM code with ISIS-CFD. Then BEM code used to check the implementation is the INSEAN PFC-1.3 solver				Fluid Dynamics in Research and Consulting	propulsion prediction with a coupled RANSE-BEM approach." The V International Conference on Computational Methods in Marine Engineering. 2013.	available through commercial licencing	
General Advancement in Knowledge Software	(D34.3) Improved procedures to study propeller-hull interaction. Improved procedures for	YES	N/A	Software	Ship Propulsion design	Starke, A.R., Bosschers, J., "Analysis of scale effects in ship	All developed software is property of MARIN.	MARIN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	optimization of hull forms with RANS					powering performance using a hybrid RANS-BEM approach". 29th Symposium on Naval Hydrodynamics, Gothenburg, Sweden, August 26-31, 2012.		
General Advancement in Knowledge Software	(D35.1) Improved procedures to study propeller-hull interaction.	YES	N/A	Software	Ship Propulsion design	All scientific results will be published in open literature, and are	All developed software is property of MARIN.	MARIN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						available on request. Starke, A.R., Bosschers, J., "Analysis of scale effects in ship powering performance". 29th Symposium on Naval Hydrodynamics, Gothenburg, Sweden, August 26-31, 2012.		

Type of Exploitable Foreground	**Description of exploitable foreground**	**Confidential : YES / NO**	**Foreseen embargo date: dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application**	**Timetable commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved.**
General Advancement in Knowledge Software	(D35.2) Free Form Deformation Tool, FreSCo+	YES	N/A	Software	Ship Propulsion design	The resulting new techniques are fully integrated into the current productive version of the FreSCo+ code. It is used in the daily research and consulting work. The use of the software is foreseen in future Horizon 2020	Access subject to bilateral agreement. Access limited to an executable form for the duration of the project only.	HSVA

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						projects as well as national research projects.		
General Advancement in Knowledge Software	(D35.3) Improved procedures to study propeller-hull interaction.	YES	N/A	Software	Ship propulsion design	All scientific results will be published in open literature, and are available on request. Starke, A.R., Bosschers, J., “Analysis of scale effects in ship powering performance”	All developed software is property of MARIN.	MARIN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
						. 29th Symposium on Naval Hydrodynamics, Gothenburg, Sweden, August 26-31, 2012.		
General Advancement in Knowledge	(D35.4) A theoretical model with a novel shape deformation technique valid for marine propeller blades has been developed and implemented; additional coding work on existing numerical optimization software and validation studies.	YES	N/A	Algorithms and Software	Ship propulsion design	Paper submitted to Ship Technology Research Journal, 2011	N/A	CNR-INSEAN

Type of Exploitable Foreground	Description of exploitable foreground	Confidential : YES / NO	Foreseen embargo date: dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved.
	Algorithms and software developed and used in combination with marine propeller hydrodynamics models from the PRO-INS package by CNR-INSEAN							

5. Impact and Exploitation of Results

5.1. WP11 - Large Area Propeller

Through the research carried out within the STREMLINE project, Rolls-Royce is proposing to further develop the large area propeller technology in 2 parallel development projects. The results generated by the STREAMLINE developed methods and tools have been very important in the decision making process to exploit the Large Area Propeller technology beyond the STREAMLINE project.

The first project to exploit the technology is within the LEANShip consortia, where we aim at demonstrating the Large Area Propeller technology on a series vessel together with a European ship operator, yard and research organisation. The aim is to optimise the vessel and the large area propeller within the current design space with minor modifications required. With these constraints we expect to improve the propulsive efficiency up to 10%.

The second project to exploit the technology is through a UK funded Rolls-Royce led demonstrator. In this project we aim at fully exploit the potential of the large area propeller where we expect an improvement in propulsive efficiency of between 15-20% across several vessel types.

The time schedule for both these projects are 2015 to 2019 as shown in figure 28:

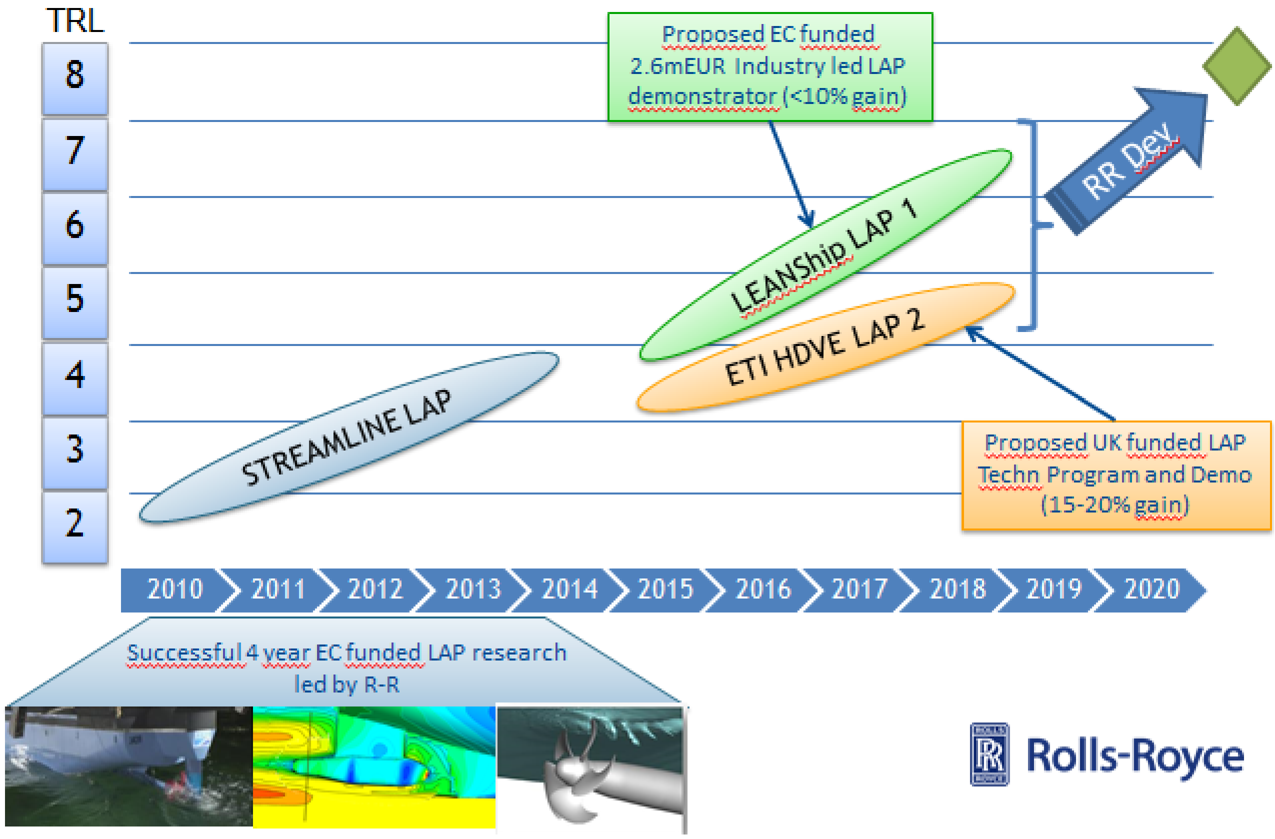


Figure 28:Time schedule for both these projects are 2015 to 2019

5.2. WP12 - Walvistaart Pod

Through the research carried out within STREAMLINE the project has demonstrated, with the use of CFD tools developed within the project, that the concept has the potential to provide the efficiency and power improvements envisaged over a conventional propeller system. The feasibility study conducted by MARIN showed that although the production and testing of a model was not achievable within STREAMLINE, it would be achievable as a future project.

Despite the advancements made within STREAMLINE, the Walvistaart Pod is still in the 'concept' phase. Therefore, there is still a requirement for further development of this technology, this will include:

- Analysis of the 2D, and 3D computations.
- Model scale testing must be completed to validate the CFD conclusions.

Once the concept has been developed, the CFD computations have been validated and the system has displayed the results that are envisaged, it is planned that the WS group will:

- Complete financing of inland navigation ship.
- Find a producer for the POD.
- Order and build a vessel.
- Extensive test trials with a vessel.
- Continue to improve design in particular size and weight.
- Develop seagoing POD.
- Develop a smaller POD for Yacht industries.

5.3. WP13 - Distributed Thrust

The concept has shown good improvements beyond the SoA, with potential operational cost reductions of up to 10%, and potential fuel savings of up to 25%. STREAMLINE has demonstrated that the concept has applications within the European Maritime Market within inland shipping, with the potential to reduce road congestion and meet CO_2 regulations and targets.

DST will be raising proposals in the first call of H2020 2014 within MG4.1, and MG4.4, for the further development of what has been achieved within the STREAMLINE project.

The STREAMLINE Benchmark Ship is being used within National German funded projects:

- Skate
- Wake

CNRS will use 2 Phase CFD Code in research projects to predict the air suction of the propulsion systems. The functionality of the code is now fully integrated into the commercial code licence, and can be used commercially.

ZF will be integrating the improved housing geometry for their rudder propeller designs. A project is now being derived to optimise the hydrodynamic performance of the azimuth thruster. Within this project, further development of the rudder propellers developed within STREAMLINE will be conducted with the aim to:

- Optimise the shape of the thruster.
- Improve the thruster body resistance and improve the wake field in the behind condition.
- Reduce running costs of the thruster.
- Improve the influence of the propeller on hull.

The research carried out and results obtained within the STREAMLINE project will be applied to the entire ZF thruster range.

5.4. WP21 - Advanced Screw Propeller Systems

With a combined optimisation of both the hull and propeller, the aim of increasing efficiency propulsive power reductions of by 8-9% have been displayed, with the potential of reducing operational cost and environmental impact.

The STREAMLINE Tanker Data set developed within STREAMLINE is at present being used within FP7 projects GRIP and SONIC. This is being used as a reference case, and therefore having a valued impact on present EC funded projects and their results.

The simulation based designs and optimisation tools developed for the hull propulsors are the subject of proposals being applied for within H2020, these include:

- Optimised Propeller;
- Twisted rudder, with combination of the ESDs within the to the propeller inflow.

Retrofit solutions with a combination of ESDs within the propeller inflow are also being addressed in H2020 projects for the application of optimised rudder and propeller configurations.

5.5. WP22 – Water jet at low speed

Following the results obtained within STREAMLINE, further analysis of the concept is required. The aim is therefore to expand of the scope of the design for the whole water jet system. The concept may be taken further and adapted for the ferry operations, from this further developments will be made in:

- The improvement of operations at low speed;
- An increase in power demand at high speed;
- An evaluation of total fuel consumption.

Experimental and numerical tools, verified through STREAMLINE, will be utilised for any future development and optimisation of the concept.

5.6. WP23 – Advanced Pods

Further development of the CRP and ICP concepts by SSPA will be dependent upon the market conditions; therefore SSPA may be bringing the CRP concept forward into H2020 proposals. At present the design of the CRP concept is being used by Rolls Royce in the design and build of a small vessel.

The ventilation experiments in a depressurised environment, conducted by MARIN have been:

- Used in demonstrations to large groups of customers
- Applied in several commercial projects (PODs and regular propellers)
- Applied in offshore industry (thruster ventilation)

5.7. WP31 – Development of Fixed Grid and Rotating Grid Coupling

Advancements within the development of the sliding interface and the overset-grid methodology have been significant.

These sliding interface techniques are being utilised within the following FP7 projects and joint industry projects, having a valued impact on present EC funded projects and the results there of:

- GRIP
- Refit2Save
- THRUST

The use of sliding interface techniques are being used for the development and design of Tidal Turbines by MARIN. This is being proposed within HORIZON 2020 project 'RESTORE', for the further development of this technology within the commercial sector.

The existing sliding interface technology implemented by ECN/CNRS in their in-house research flow solver ISIS-CFD was used and validated throughout the STREAMLINE project. It is available in the commercial version FINETM/Marine and mainly used in marine industry to take account for propeller effects.

5.8. WP32 – Grid Adaption

The Grid Adaptation techniques are being used within Commercial and Defence projects by MARIN. These techniques have now been developed further to include pressure fluctuations on the hull. They are also being used within the FP7 project SONIC to determine underwater radiated noise.

The Automatic Grid Refinement technique by ECN/CNRS in their in-house research flow solver ISIS-CFD was used and validated throughout the STREAMLINE project. It is available in the commercial version FINETM/Marine and used in the marine industry, mainly for sea transport, and also from naval architects for sailing boats.

5.9. WP33 - Prediction of Cavitation

The ventilation and erosion prediction solvers developed within STREAMLINE are being used to perform virtual experiments, and are being used in the decision making process at the design stage of new systems. These computational models developed are also being used at present within the assessment of innovative concepts for new projects.

5.10. WP34 - RANS/BEM Coupled Method

Hybrid solvers have now been shown to be suitable for application as software for industrial design, and are being used within new projects by CNR- INSEAN addressing the greening of marine transports as well as the development of marine current turbines. These tools are also being used by HSVA within Commercial, National and EU projects on a daily basis.

Since 2013 the RANS-BEM Coupled Method developed within STREAMLINE has been used within commercial projects by MARIN, as well as within the FP7 project GRIP.

MARIN will be utilising these design studies within H2020 projects and will use this methodology in the design on their propulsion systems.

5.11. WP35 – Design Optimisation

Tools developed within STREAMLINE are being used with National Projects by HSVA, and commercial projects by MARIN for both hull and duct techniques. MARIN have now extended these methods to include free-surface waves and will be utilising these techniques in future projects. The numerical optimization platform developed by CNR-INSEAN is currently used in commercial projects and will be proposed for R&D projects under H2020.

6. Report on Societal Implications

A General Information *(Completed automatically when Grant Agreement Number is entered)*	
Grant Agreement Number	233896
Title of Project	STREAMLINE
Name and Title of Coordinator	Paul Greaves - RRPE

B Ethics	
1. Did you project undergo an Ethics Review (and / or Screening)? **If Yes:** have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports?	**NO**
2. Please indicate whether your project involved any of the following issues (tick box 'X')	
RESEARCH ON HUMANS	
Did the project involve children?	
Did the project involve patients?	
Did the project involve persons not able to give consent?	
Did the project involve adult healthy volunteers?	
Did the project involve Human geneti9c material?	
Did the project involve Human biological samples?	
Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRTYO / FOETUS	
Did the project involve Human Embryos?	

Did the project involve Human Foetal Tissue / Cells?	
Did the project involve Human Embryonic Stem Calls (hESCs)?	
Did the project on Human Embryonic Cells involve cells in culture?	
Did the project on Human Embryonic Cells involve the derivation of cells from Embryos?	
PRIVACY	
Did the project involve processing of genetic information or personal data (e.g. health, sexual, lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
Did the project involve research on animals?	
Were those animals transgenic small laboratory animals?	
Were those animals transgenic farm animals?	
Were those animals closed farm animals?	
Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
Did the project involve the use of local resources (genetic, animal, plant etc?)	
Was the project of benefit to the local community (capacity building access to healthcare, education, etc?)	
DUAL USE	
Research having direct military use	**NO**
Research having the potential for terrorist abuse	**NO**

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Types of Position	Number of Women	Number of Men
Scientific Coordinator		1

Work Package Leader		12
Experienced Researchers (i.e. PhD holders)		54
PhD Students		5
Other		
4. How many additional researchers (in companies and universities) were recruited specifically for this project?		
Of which, indicate the number of men:		

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	NO

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
☐	Design and implement an equal opportunity policy	○	○	○	○	○
☐	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
☐	Organise conferences and workshops on gender	○	○	○	○	○
☐	Actions to improve work-life balance	○	○	○	○	○
○	Other:					

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ If Yes- please specify

☑ **No**

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ If Yes- please specify

☑ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

☑ If Yes- please specify: STREAMLINE Dissemination Video

○ No

F Interdisciplinary

10. Which disciplines (see list below) are involved in your project?

- ○ Main discipline[1]: Engineering and Technology

○ Associated discipline[1]:	○ Associated discipline[1]:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	**NO**

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ○ No
- ○ Yes- in determining what research should be performed
- ○ Yes - in implementing the research
- ○ Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	**NO**

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)

- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture Audio-visual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ○ European level
- ○ International level

H Use and dissemination

14. How many Articles were published / accepted for publication in peer-reviewed journals?	**3**
To how many of these is open access provided?	
How many of these are published in open access journals?	**2**
How many of these are published in open repositories?	
To how many of these is open access not provided?	
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ☑ no suitable open access journal available ☑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ Other[2]: ……………	
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**2**

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	
	Registered design	
	Other	**1**

17. How many spin-off companies were created / are planned as a direct result of the project?	
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

☑	Increase in employment, or	☑	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs: Difficult to estimate / not possible to quantify	*Indicate figure:*

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ☑ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

☑ Yes ○ No

22. Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	❑	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
❑	Brochures /posters / flyers	❑	Website for the general public / internet
❑	DVD /Film /Multimedia	❑	Event targeting general public (festival, conference, exhibition, science café)

23. In which languages are the information products for the general public produced?

❑	Language of the coordinator	☑	English
❑	Other language(s)		

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. **NATURAL SCIENCES**

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, volcanology, paleoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 **ENGINEERING AND TECHNOLOGY**

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. **MEDICAL SCIENCES**

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. **AGRICULTURAL SCIENCES**

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. **SOCIAL SCIENCES**

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. **HUMANITIES**

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]