Project no. COOP-CT-2005-017725

Project acronym: Swirl Jet Study

Research to evaluate the technological application of swirling jets in the fields of seabed excavation,
vessel propulsion and underwater cleaning

Co-operative Research Projects (CRAFT)

# Deliverable D3/D8
# Project Technical Review

Due date of deliverable: late-December 2006
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Start date of project: Dec. 2005 Duration: Two years

Lead contractor: SILT Revision: [Final 1]

| Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006) | | |
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| **Dissemination Level** | | |
| **PU** | Public | |
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| **RE** | Restricted to a group specified by the consortium (including the Commission Services) | |
| **CO** | Confidential, only for members of the consortium (including the Comminssion Services) | * |

**CONTENTS**

# 1.0 INTRODUCTION AND BACKGROUND

This document represents part of the output from the Project Technical Review workpackage (Workpackage WP RE) of the Swirl-jet study. The original Description of Work for this project foresaw the project lasting 18months and producing three separate deliverables from this (WP RE) workpackage, intended to coincide with the 25% (deliverable D3), 50% (deliverable D8) and 95% (deliverable D15) project spend milestones, respectively.

At an early stage in the project, however, it became evident that in order to realise its full potential, the project would need to be extended to 2years. Initial application for this extension was made in March 2006, by the project coordinator (KORT), with final approval of the application being received from the EC in September 2007. Formal application for this extension necessitated a detailed revision of the Description of Work, which was duly submitted as Description of Work (modified), dated 12 July 2007. The revisions incorporated into the Description of Work (modified) took into account not only prolongation of the project, but also changes to the scheduling and content of some of the workpackages.

Because of difficulties experienced at the start of the project, which will be dicussed shortly, the project did not proceed as quickly as was anticipated and the mid-point (month 9) on the original 18month programme was reached with only 25% of the EC budget having being spent. Documents submitted as part of the original mid-Term Reporting (for the 18month project) included a project technical review that was intended to satify the requirements of deliverable D3.

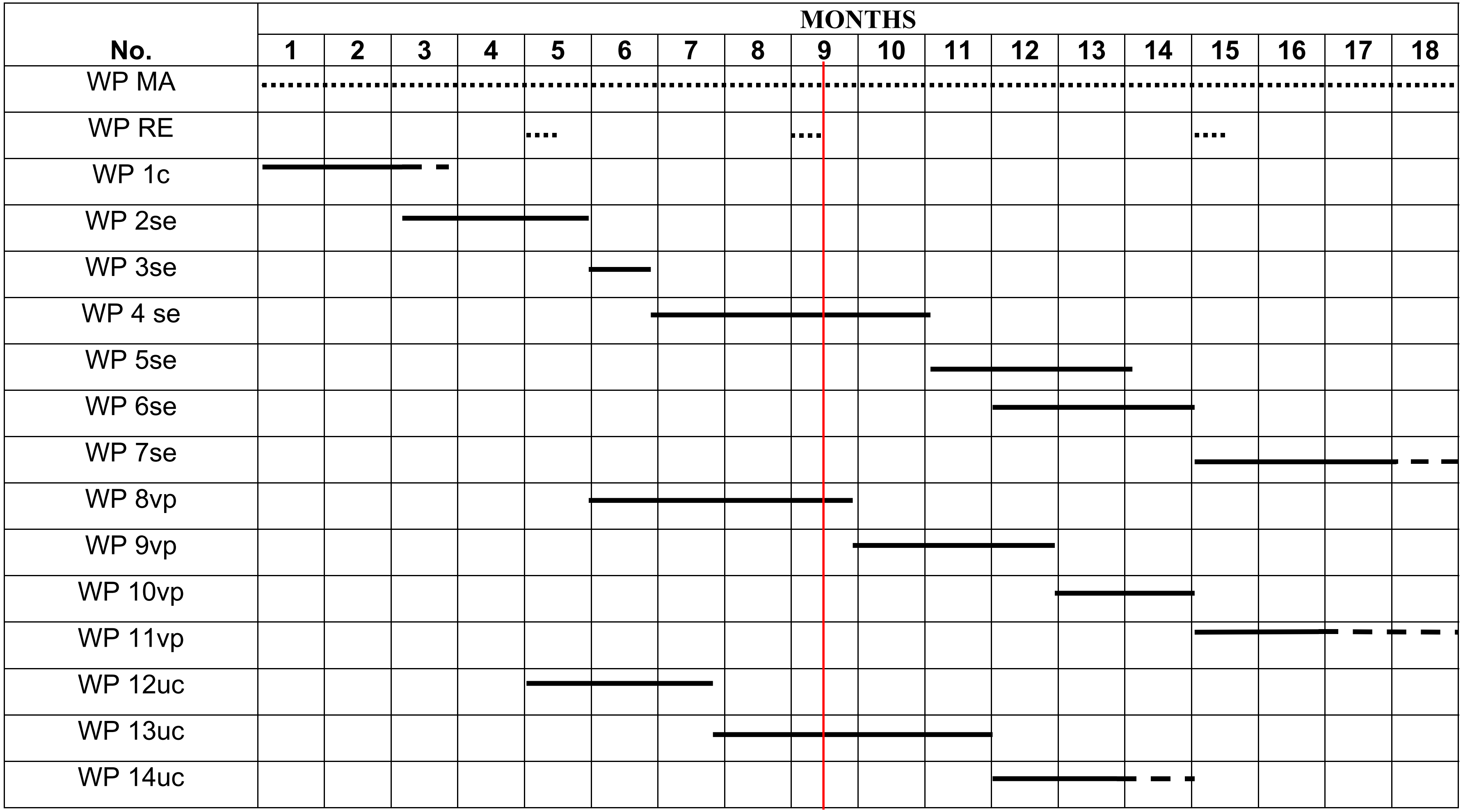
With extension of the project to 2years, the 50% milestone coincided approximately with the (month 12) mid-point of this extended work programme. A revised mid-term Activity Report (upgraded) was duly submitted (retrospectively, in October 2007), which provided a detailed technical review of the project at this month 12 mid-point.

As outlined in the Descripton of Work (modified), the intension was to combine deliverables D3 and D8 into a single deliverable, which would review the technical status of the project at month 12 (the mid-point of the 2year project). The present document is this D3/D8 deliverable and is submitted, retrospectively, to coincide with submission of the upgraded mid-term Activity Report. Much of what is presented in this deliverable is also included in the Activity Report (upgraded), dated October 2007.

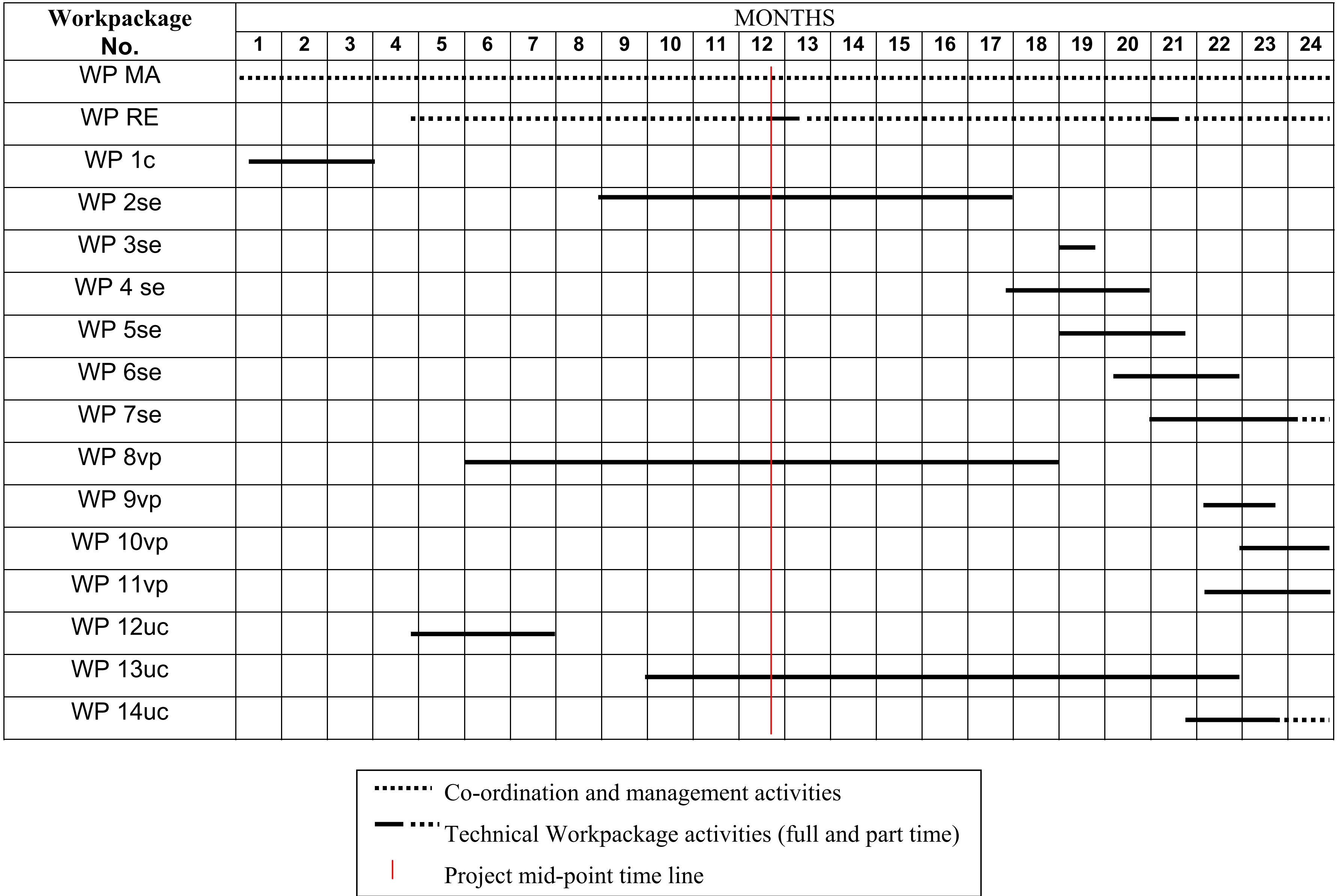
# 3.0 CHANGES TO PROJECT PROGRAMME

The following two bar charts show the original (18month) and revised (2year) project plan. The revised (2year) project plan has since been incorporated into the Description of Work (modified), and is the programme that the project will adhere to during its second 12 months. Changes to the scheduling and duration of individual workpackages, and the reason for these changes, are discussed in later sections of this report. Although no changes have been made to the overall budget or to the total person months of effort to be expended on the project, some adjustments have been made to the person month input to individual workpackages and these are also discussed.

# Project Bar Chart (original – 18month project)



## Project Bar Chart (revised – 2year project)



# 3.0 PROJECT OBJECTIVES AND ACHIEVEMENTS DURING THE FIRST 12MONTHS

## 3.1 Project Overview and Restatement of Project Objectives

As stated in the original contract Description of Work, the Swirl-Jet Study had a long list of objectives formulated around the six basic requirements of FP6 Co-operative Research projects.

Central to the main aims of the project is the desire to advance the commercial interests of the three lead SMEs by providing them with the opportunity and financial support to undertake research that would otherwise be difficult for them to carry out. The research is also intended to further the acquisition of knowledge by the SMEs and so help them to better compete in the international marketplace. The research element is being carried out mainly by the RTDs, who are perceived as benefiting from the opportunity to do fully-funded research.

A particular feature of this project is that the three lead SMEs each have separate and rather different commercial interests and applications, which they wish to see advanced by this research. However, the three applications are linked by a common technical theme, which is that they each depend on, or utilise, the properties of swirling fluid jets. The Swirl-Jet Study was thus conceived as a 3-in-1 project, built around this common technical theme.

The original idea that a particular type of swirling fluid jet (a conical fan-jet) might provide an even closer unifying theme for all three applications was shown at an early stage not to be the case. The project has thus moved forward on the following basis and with the following objectives:

For the vessel propulsion application, existing ducted-propulsor design practice has provided an appropriate starting platform. KORT's existing duct and propeller designs are being studied by UNEW, using state-of-the-art research techniques, with a view to establishing suitable design modifications that will improve operating performance (thrust, free-running speed, fuel economy, etc.). UNEW, being the primary RTD for the vessel propulsion application, is benefiting not only from interfacing with a commercial organisation (KORT) with considerable in-house experience of applying ducted propeller technology, but UNEW has the opportunity to renew its own research capability in this area. To guide the research for this application UNEW and KORT have formed a specific Vessel Propulsion Steering Group.

Participants in the seabed excavation and underwater cleaning applications have also formed closer ties through the recognition that a similar type of swirling jet is appropriate for both their applications. This stems in part from the fact that both applications involve jets impinging against a surface for the purpose of removal of the surface layer of material; but a further point of commonality is that one particular end use – that of removal of biofouling from vessels – has the potential to utilise both the underwater cleaning nozzle and a modified form of seabed excavation ducted propeller. Therefore, SILT and HTS (as lead SMEs) and INSEAN, UMA and USE (as RTD Performers), who are the key participants in these two applications, have also elected to work more closely together and to exchange ideas and information.

Nevertheless, participants are striving to adhere to the main project objectives and to keep as closely as possible to the original programme of work. Application to extend the project to 2 years, initially made at the request of the RTD Performers, will not in itself change the overall scope of work. It will, however, enable participants to cope better with the complexity and ambitious nature of the project.

The project has also used the excellent contacts within the consortium to access information from the wider scientific community, thus avoiding unnecessary duplication of research and at the same time furthering the aims of the project. This aspect is further discussed in connection with the dissemination of knowledge in Section 7.0.

## 3.2 Reporting Period Objectives

It was an original objective of the project, that by the mid-way point (month 12 of the 2year project), all three applications would have been advanced to the stage where some degree of commercial value would have been demonstrated and sufficient technical understanding would have been developed to enable the project to run smoothly to a conclusion.

The workpackage status description, given in Section 4.0, provides a detailed breakdown of the research activities undertaken to date. It indicates that the initial Design-basis review covering all three applications, which was intended to kick-start the project, has been successfully completed and provides the basis on which the project has moved forward. The three reports that constitute the Design-basis review are incorporated into deliverable D1.

The following description of reporting period objectives is set out under headings according to each of the three application areas (project modules).

### 3.2.1 <u>Underwater Cleaning Application</u>

As part of this Design-basis review an initial design for the underwater cleaning nozzle has been identified and a prototype of the nozzle has since been fabricated, and tested in the laboratory, by UMA. For this testing a purpose-built tank and flow-visualisation arrangement has been constructed that will also be used for further prototype nozzle testing. Improvements to this early design have already been identified and preliminary numerical modelling of the flow within this nozzle (using the FLUENT code) has been carried out by UMA with a view to more accurately defining those characteristics considered necessary for underwater cleaning. USE has developed a 3-D numerical code to simulate the interaction of an underwater cleaning swirl-jet with a wall. This same numerical code will also be very helpful for the seabed excavation application. USE has also built a computer cluster and installed the necessary software libraries to be able to handle the complex equations required to carry out these simulations. Preliminary results have been presented as part of a report, which together with the UMA work, forms deliverable D5.

The underwater cleaning application is currently (January 2007) at the stage anticipated by the stretched (2 year) programme of work, provided in the Management Report (modified). Work currently in-hand comprises further more detailed design and flow simulation studies aimed at optimising the internal geometry of the nozzle. Once an ideal flow velocity profile has been developed, USE will then carry out further numerical impingement simulations. Although HTS have not been able to participate as fully as was anticipated (due to injury to their technical manager), other project team members have provided support.

Work carried out to-date suggests that a nozzle design and jet flow characteristics suitable for commercial underwater cleaning application will be forthcoming from the project. The project has also identified a particular avenue of application (biofoul removal from underwater surfaces coated in foul-release paints) that could provide a novel and potentially very beneficial outlet for this technology. Pursuing this specific application is seen as driving the work and providing an additional objective for the second half of the project.

### 3.2.2 Vessel Propulsion Application

The vessel propulsion application has also made good progress, generally in accordance with the original programme and according to the original objectives. At the start, a particular design of high-swirl propeller (the plate propeller) was fabricated and tested in model form in an aft-flared duct in order to establish the merits of utilising swirl (and the conical fan-jet) for vessel propulsion. This preliminary testing determined that there is no particular advantage to using high swirl over more conventional designs of ducted propulsor. The vessel propulsion application is thus now moving forward on the basis of utilising conventional propeller and duct designs, including KORT's own in-house design, but with a view to seeking measurable improvements in propulsion performance. UNEW are currently carrying out numerical modelling and performance simulation, starting with a base design for which a considerable amount of (published and in-house) full-scale, model scale and numerical test information is available. They are trying out a range of modification to both the duct and the propeller to establish to what extent changes to the flow behaviour improve or degrade propulsion performance. This work is being done using UNEW existing in-house computer codes and also the commercial FLUENT code.

This phase of computer modelling work (associated with workpackage WP 8vp) has been extended (both time-wise and in terms of man hours) to enable a wider range of possible design modifications to be researched, prior to any further scale-model testing in the cavitation tunnel. This is linked to a difficulty that has arisen regarding the programming of the UNEW research work, resulting from the Emerson cavitation tunnel having to be temporarily taken out of commission for modification and essential maintenance work. As a result, the main model testing phase of work (workpackage WP 9vp) has had to be pushed back and curtailed somewhat, with man hours being transferred to WP 8vp to compensate. The changes to the overall project programme are indicated in the bar chart in the accompanying Management Report (revised). The net effect in terms of the objectives for this reporting period are neutral, since it was not anticipated that the numerical work would have been wholly completed or the main phase of model testing started at this mid-term stage in the stretched (2 year) programme. In terms of impact on the second half of the project, and meeting the overall objectives for the vessel propulsion application, the programme changes are also seen as neutral to potentially beneficial. They are seen as beneficial in that a greater range of design modification can be studied numerically, enabling more selectivity and design optimisation to be completed before committing to model fabrication.

A number of reports have been prepared covering the work already undertaken by UNEW and are included in Appendix A. Other than UNEW's contribution to deliverable D1, there are no other deliverables arising from the vessel propulsion module due at this time, based on the modified stretched programme.

#### 3.2.3 Seabed Excavation Application

The biggest change to the original work programme and objectives for this first reporting period has been with regard to the seabed excavation application. The programming changes are clearly evident from the two bar charts presented in the accompanying Management Report (revised), which compare the original (18 month) programme with the proposed revised and stretched (2 year) programme. These changes (essentially a delay to the start of ducted propeller model testing) have been implemented in order to provide more time to better understand the factors that govern the ducted propeller seabed excavation behaviour. Once the model is fabricated and installed in the INSEAN cavitation tunnel, further modification becomes very difficult. This is partly because the model is not easily accessible, but also because the tunnel running costs and pressure from other tunnel users means that the testing has to be expedited in one continuous operation.

The most expensive component of the model – the propeller – has to be designed in such a way that it provides the means for achieving enhanced excavation behaviour. At the start of the project it was not clear whether SILT's existing Kaplan propeller was critical for this purpose, or whether some alternative propeller/duct design might not be more appropriate. Delaying the start of the INSEAN work was thus seen as essential to enable further desk-study work (a continuation of the Design-basis review) to be undertaken to provide the basis for decision-making with regard to the design of the ducted propeller model. It also provided the opportunity for feedback of information from the vessel propulsion and underwater cleaning applications to influence this decision-making process. As already mentioned, similarity in form and likely performance behaviour between the seabed excavation and underwater cleaning jets had been identified during the Design-basis review.

Selection of the design of ducted propeller for seabed excavation model testing has now been completed and the model is in the process of being fabricated by UNEW. In addition, design of the test facility and, in particular, the selection and calibration of measuring equipment needed to undertake the visualisation and PIV flow measurement studies, is now also complete. The testing itself will begin very shortly and, once started, the plan is to adhere rigidly to the original programme and work content.

A report detailing the preliminary work carried out by INSEAN during this first phase of the project is available for viewing on the project website. On the basis of the revised and stretched (2 year) programme, no other specific deliverables are due for this module of the project at the present time.

## 3.3 Contractors Involved, Work Performed and Main Achievements During Reporting Period

The following contractors, in particular, have been active in performing work during this period: KORT, SILT, UNEW, UMA, USE, INSEAN.

KORT, as project co-ordinator, has undertaken the coordination activities on the project, as well as organising and hosting the two project meetings. In addition, it has been active in liaising with UNEW on the research to do with the vessel propulsion application. It has also liaised closely with SILT in trying to resolve the aforementioned technical and programming difficulties that have confronted the project, and has represented SILT's interests in connection with the design of the model propeller to be fabricated by INSEAN. The design of propellers was an area that SILT had very little prior experience with.

SILT, for its part, has been actively engaged not only in technical management, but in leading the desk study research to help define the design characteristics of the ducted propeller that will be used for seabed excavation physical modelling studies. This desk study research has comprised literature searches, internet searches, talking to recognised authorities external to the project, revisiting its own technical database and regular telephone and face-to-face discussions with other project participants. In addition, it has re-furbished the previously used small-scale ducted-propeller, with a view to carrying out further testing to help define the ducted propeller jet impingement characteristics. These small-scale model tests will be carried out in parallel with those to be performed by INSEAN. It has also represented HTS's interests at meetings and in relation to discussions with other project participants (occasioned by the injury to HTS's technical manager), and has prepared a draft set of design drawings of the static swirl nozzle that form the basis for the underwater cleaning application.

Although HTS has not been particularly active during this period, for the reason outlined earlier, it participated in the first project meeting and has arranged for the preparation (by its partner organisation) of a preliminary set of machine-shop drawings of the static swirl nozzle. In addition, it has prepared preliminary sketches of a set-up for undertaking controlled testing of the underwater cleaning nozzle under simulated field conditions.

UMA has been particularly active on two fronts – in fabricating and testing of a number of static swirl nozzle designs suitable for underwater cleaning. Thus far, these physical model tests have enabled the basic laboratory test set-up and fluorescein/PIV visualisation techniques to be bench-tested. UMA has also carried out a number of computer numerical model simulations using different nozzle geometries in order to try and achieve the most appropriate form of underwater cleaning jet. Very recently, a significant breakthrough has been made, with simulation of a jet that appears to offer particularly attractive feature for surface removal of material. This same form of jet, which is seen as applying a high velocity wall-jet flow over a large footprint area, is also thought to be appropriate for enhanced seabed excavation.

USE has carried out complementary numerical studies to those of UMA, but modelling the impingement behaviour of swirling jets. The basic methodology for these numerical simulations has now been thoroughly tested and verified. USE will shortly examine the impingement behaviour of the new form of jet identified by UMA.

# 4.0 WORKPACKAGE PROGRESS DURING THE FIRST 12 MONTHS

The original Project Plan (see 18month project bar chart) shows the various workpackages and their individual start and end dates. This was the Project Plan that initiated the project and was intended to run for 18months.

At the request of a number of the RTDs, but UNEW in particular, KORT applied to the EC for the project to be extended to 2 years. At the time of this application, in March 2006, it was anticipated that extending the project would simply entail stretching a number of the workpackages to enable them to be carried out in a more appropriate time frame. In the event, for reasons already outlined, a number of additional changes have had to be made to the Project Plan.

The amended Project Plan (see 2year project bar chart) takes account not only of the extended project time frame but also of the changes to the individual workpackages that have been necessary during the first reporting period and which are considered necessary to complete the project within the agreed (2 year) timeframe.

Each of the workpackages that have been active during this first reporting period will now be discussed. Later in this section, a brief discussion will be given about revisions to workpackages during the subsequent (second) reporting period.

The technical workpackages are discussed first, with the project management (WP MA) workpackages being dealt with in Section 5.0.

## 4.1 Technical Workpackages

This section should be read while referring to the revised Project Plan (2year project bar chart). Note that there are no changes to the overall project budget and the changes to the duration and sequencing of workpackages has come about due to some RTDs requesting more time to complete their elements of the project and technical constraints that have caused some workpackages to be pushed back in time. As far as possible the project has tried to adhere to the original schedule of work.

A brief review of each technical workpackage will now be given

### 4.1.1 Workpackage WP 1c (Design-basis review)

The purpose of this workpackage was to enable everyone on the project to contribute to an initial re-appraisal of the basic tenets of the project and to develop ideas about design features for each application that could then be taken forward to the modelling and testing stages.

It had been intended that the concept of swirling jets, and the conical fan-jet in particular, would provide a focal point for this initiation stage of the project. However, as noted earlier, the conical fan jet had been shown to have little or no potential for seabed excavation and underwater cleaning. It was also subsequently shown, by UNEW, to have no particular advantages for vessel propulsion. Thus workpackage 1c became, to some extent, a reappraisal of the basis on which the project and the individual applications wished to go forward.

Although all of the main participants contributed to this workpackage, SILT was tasked with pulling all of the information together. This was deemed appropriate, since SILT alone had a grasp of all three applications and SILT was responsible for creating the project and bringing all of the participants together. Three reports were prepared, covering each of the three project applications, and these have subsequently been consolidated into deliverable D1.

Not all of the ideas and concepts presented in these reports have been pursued by the individual project applications. However, the Design-basis review provided an important platform for decision-making that has helped to guided subsequent work on the project.

In particular, key project technical advancements that stemmed from workpackage 1c were:

- For the seabed excavation and underwater cleaning applications the jet had to be made more consolidated (rather than splayed out) in order to deliver more concentrated energy to the impingement surface. This, in effect, meant that the overall swirl content of the jet would need to be reduced, rather than increased. However, swirl was still seen as an essential component of the jet.
- A possible means for increasing the consolidation of a ducted-propeller jet, by inserting a sleeve into the duct-outlet was identified.
- A preliminary design of swirl nozzle for the underwater cleaning application was evolved. This design was based on previous published studies of swirling jet behaviour that seemed to offer potential for underwater cleaning. The basic design provided flexibility in that various adjustments could easily be made to modify the flow behaviour, without having to completely redesign the nozzle. This prototype nozzle design was thus seen as a stepping-stone towards a working prototype that could be used for simulated field-testing.
- A potential new application for the underwater cleaning jet was identified, in the shape of: removing biofouling from ships' hulls coated with foul-release paints. This application was discussed with INTPA (a developer and manufacturer of these paints) at the first project meeting.

During this workpackage it also became evident that the project needed to make use of its excellent contacts with the wider technical and scientific community in order to gain access to additional information. Three benefits were seen as stemming from this outward communication: 1) it would provide a way of accessing existing knowledge at no expense to the project, 2) it would provide an additional means of peer review by external authorities, 3) it would enable information about the project to be broadcast to the wide scientific and technical community. Each participant was, therefore, asked to provide a list of names of people who might be seen as helpful for the project to communicate with, and to update this list on a regular basis.

In addition, during this workpackage, the project website: www.swirl-jet.org was set up to provide a platform for communication within the project and for the project to communicate with the outside world.

There were no changes to the consortium during workpackage 1c, although as noted earlier, HTS's contribution to the project was seriously impaired through the injury to Mr Brotski, their technical manager. Workpackage 1c started and was completed more or less according to the original project workplan.

### 4.1.2 Workpackage WP RE (Project technical review)

This workpackage provides for technical oversight of the project by the various project technical managers, both SMEs and RTDs. This continues to be the primary function of this on-going workpackage. At set intervals during the project, the results of this workpackage will be consolidated into a report deliverable designed to provide a record of the way the project has been technically guided. For reasons outlined in the Introduction, the present report includes deliverable D3 and deliverable D8, which have been retrospectively incorporated into one document.

However, in order to provide further technical assistance to the seabed excavation (suffix se) and underwater cleaning (suffix uc) workpackages, additional desk-study work has been carried out within Workpackage WP RE.

This additional desk-study work was started in March 2006 with the express purpose of trying to identify and understand the particular characteristics of the ducted propeller jet that provide enhanced excavation, and how such an enhanced-excavation jet might evolve from the normal ducted propeller jet. This also has relevance to the underwater cleaning application, because the enhanced-excavation jet is considered to offer potential for certain underwater cleaning applications such as biofoul removal.

This desk-study work has been led by SILT, but with contributions from all of the participants able to provide relevant technical information.

The plan is for design guidance information stemming from this desk-study work to feed into the various technical workpackages. Periodically, the output from this desk-study work will also be consolidated into separate reports, which will form supporting appendices to the main workpackage deliverables. For instance, it is planned to incorporate desk-study work currently being undertaken on the behaviour or propeller wakes into deliverable D4, and similar studies into the effects of swirl number and nozzle geometry into deliverable D6.

### 4.1.3 Workpackage WP 12uc

The objective of this workpackage was to fabricate and test an initial prototype of underwater cleaning swirl nozzle; a preliminary design for which was included in Deliverable D1, which represented the output from Workpackage 1c. The plan was for HTS to fabricate this nozzle and for UMA to carry out the laboratory testing of the nozzle, with HTS providing technical oversight.

In the event, partly because of the loss of key personnel, HTS were not able to fabricate the nozzle. Thus, for UMA to progress with their agreed scope of work they took the initiative and fabricated a prototype nozzle, based on the preliminary design presented in deliverable D1. They did this in two ways:

- They built a physical model out of plastic and tested it in a small water-filled tank, using a small electrical pump to drive the fluid flow through the nozzle. The resulting jet was visualised using a fluorescein dye injected into the pump flow output, with the jet illuminated by a laser sheet. Free- and impinging-jet conditions were examined.
- They built a numerical model, using a piece of software known as SolidEdge and studied the flow through the nozzle and outwards into the free jet using FLUENT, a sophisticated (SolidEdge-compatible) flow-modelling piece of software.

Early trials with the test-tank set-up, as well as initial computer runs, helped to provide confirmation that the numerical simulations could indeed accurately model the real-world test set-up and jet behaviour. However, it was evident that the type of jet produced was not going to be suitable for underwater cleaning, because it spread too quickly on entering the ambient fluid, losing energy through viscous interaction and mixing. Numerical simulation also confirmed the jet to be in a broken (sub-critical) condition as it formed in the nozzle, giving rise to divergent downstream (free-jet) behaviour.

It was thought that this undesirable behaviour stemmed from two features of the physical model set-up:

- The swirl-nozzle itself was not perfectly fabricated and had many internal rough edges, and the nozzle did not conform particularly closely to the original preliminary design
- The discharge output from the pump was such that the flow rate through the nozzle meant that the Reynolds number was too low to correctly represent the flow condition for an underwater cleaning jet.

Note that certain aspects of swirling jet behaviour are Reynolds number (or flow rate) dependent. In this case it was felt that the physical testing was being done below some critical (but undefined) Reynolds number. However, a very encouraging feature of this early testing was that the physical model and numerical simulation results appeared to validate one another. This meant, for the future, that it would be possible to avoid some of the more expensive and time consuming physical model testing, in favour of more cost-effective numerical simulation. This was a particularly important milestone to have achieved

Because of this interchangeability of numerical and physical model testing, workpackages WP 12uc and WP 13uc became strongly interlinked and this enabled the two workpackages to be run partly concurrently. For the purpose of indicating the end date for workpackage WP 12uc on the revised project workplan it is shown as ending in July 2006.

In addition to the UMA research carried out as part of Workpackage 12uc, USE has also undertaken numerical flow simulation in order to investigate swirling jet impingement behaviour. Unlike the UMA (FLUENT 3-D) modelling, which incorporated viscous (turbulent) flow-behaviour assumptions, and can simulate asymmetric flows, the USE modelling has been entirely non-viscous and axi-symmetric. However, this approach has been shown to be valid and very helpful for analysing even very complex flows, in situations where the flow Reynolds number is high and where the viscous content is limited.

The approach requires considerable computing capacity and in order to carry out the required number of iterations, USE has developed means for clustering several processors together and operating them in parallel. A number of test simulations have been carried out, varying the distance of the nozzle from the wall, the swirl content of the jet and the jet Reynolds number. A wide range of different jet impingement behaviours has been shown to occur.

Because this modelling requires the flow input parameters to be accurately defined in advance, and hitherto the flow parameters for an optimised underwater cleaning jet have not yet been defined, further application of this jet impingement modelling capability has been deferred until later in Workpackage WP 13uc.

The output from Workpackage 12uc has been presented in deliverable D5.

#### 4.1.4 Workpackage WP 13uc

This workpackage is currently ongoing and it effectively commenced at the beginning of September 2006.

UMA has fabricated a second prototype underwater cleaning nozzle (this time out of aluminium) on a CNC milling machine. This is a much improve nozzle compared to the design originally envisaged, and has the benefit of being better fabricated (less internal rough edges) and with a larger number of more accurately machined flow-turning (swirl-creating) blades.

An additional feature of this nozzle is that it incorporates a tapered throat section downstream from the swirl-chamber, designed to accelerate the flow before its outlet from the nozzle. This feature, it was felt, would help to decrease the swirl content of the flow; which the desk-study research had indicated was responsible for the instability of the jet from the first prototype nozzle.

Although the jet velocity is higher with this constriction, it is still not possible (because of the limited pumping capacity) to increase the flow rate into the nozzle. The jet penetration into the ambient fluid is greater with this new nozzle and there is significantly less initial interaction and mixing. Nevertheless, the jet still features a flow deficit on the axis. This axial velocity deficit has also been confirmed by additional numerical modelling of the new nozzle design, which has also included a number of variants to the second prototype nozzle geometry.

However, all of the physical model tests carried out by UMA with the second nozzle and validated by FLUENT simulation, have again confirmed the ability of the SolidEdge/FLUENT combination to accurately model swirling flow behaviour within the nozzle.

Very recently, and following a suggestion made at the 4-5th December 2006 project meeting by SILT, a slightly different nozzle design has been computer simulated. This incorporates longer turning blades (designed to increase the nozzle through-flow) and a central plug (designed to mimic the propeller hub in the ducted-propeller set-up). For the first time, a jet with an excess of axial velocity has been produced in the numerical simulations.

In terms of the immediate future for this workpackage, it is hoped to suitably modify the existing high-quality physical model, according to the suggested revised design features stemming from the SolidEdge/FLUENT numerical modelling. This modified physical nozzle will then be tested in the water tank using both the existing pump and a higher-pressure pump.

In addition, the plan is to get USE to undertake further jet impingement simulations, based on more specific flow input parameters.

#### 4.1.5 Workpackage WP 2se

Work on this workpackage started in August 2006, somewhat later than originally planned. As already mentioned, this delay was to enable more time to be given to a consideration of the flow characteristics from the ducted-propeller and particularly the way in which the jet evolved under different bed impingement conditions.

A particularly critical decision had to be made at the start of this workpackage, as to whether to adopt the existing duct/propeller geometry, embodied in the full-scale equipment, or to opt for a different arrangement that might provide enhanced excavation capability.

In the event, a decision was taken to fabricate the model to as closely match the existing SILT ducted-propeller set-up as possible. This was on the basis that if the model was operated under the appropriate impingement conditions it should be possible to see how the impinging flow evolved to achieve enhanced excavation. If a different model design was used, there was a good chance that it would be wrong and the opportunity to identify the key factors that determine enhanced excavation behaviour would be lost.

INSEAN commenced this workpackage with a detailed consideration of: the appropriate model scale, how the model would be operated within its large cavitation tunnel facility, what would be the best means for visualising the flow in an impinging and non-impinging condition and at different impingement distances from the surface, and how best to measure the forces both exerted by the propeller and experienced by the wall.

INSEAN initially requested information from SILT regarding details of the geometry of the duct and the propeller. Unfortunately, SILT did not have sufficient detail about the design of the propeller and did not have ready access to either a propeller or to the original design data to enable INSEAN to commence fabrication. This situation was resolved by SILT providing as much detail as possible to KORT, including photographs of the propeller, so that KORT could generate blade profiles, root section and boss details for INSEAN to utilise. This was an example of how participants have pooled their knowledge and expertise to help the project forward.

INSEAN began fabricating the model in September 2006 and will shortly be in a position to commence testing.

Although this workpackage is still in progress and the output deliverable D2 is not expected until mid-April 2007, a summary of work to-date carried out by INSEAN has been prepared to accompany this mid-term report. The INSEAN report is available for viewing on the project website.

#### 3.1.6 Workpackage WP 8vp and WP 9vp

It was provisionally intended to run these two workpackages consecutively, but as with the underwater cleaning application, the boundaries between numerical (WP 8vp) and physical (WP 9vp) modelling have become overlapping. Some physical model testing has already been completed, although the bulk of this work has, as earlier pointed out, been delayed due to the Emerson cavitation tunnel being temporarily taken out of commission. This section of the report describes the work that has been completed, jointly, on these two workpackages.

UNEW commenced with workpackage WP 9vp in May 2006, having taken the decision at the end of the design-basis review stage, to try out the concept of a high swirl propeller. The propeller design selected was the so-called 'plate propeller', used by SILT for its most recent seabed excavation field trials. A 1:2.68 scale model of the propeller was fabricated and tested in the University's cavitation tunnel.

Open water tests at different advance coefficients revealed that the propeller efficiency and thrust coefficient were significantly lower than those of a conventional propeller and the torque coefficient was significantly higher. In addition, a number of undesirable cavitation patterns were also observed.

The propeller was then tested in the same way, but this time placed inside a duct to simulate the effect of a flared nozzle. The duct was an existing accelerating duct available at UNEW, but used in a 'decelerating' orientation. Performance measurements were made, as with the non-ducted tests, and PIV testing was also carried out.

The results indicated that the 'plate propeller', operating in a duct, suffered from cavitation effects throughout the operating range and therefore propulsion performance was significantly degraded.

A report has been prepared describing the study work carried out to examine the 'plate propeller'. This report is available for viewing on the project website and will eventually be incorporated into deliverable D10, once the remainder of the physical model testing is completed (this will be later in the second half of the project).

In accordance with the original intent for workpackage WP 8vp, numerical simulations have also been carried out using UNEW's existing ducted-propeller analytical software (UPCA'91). The software has been modified to perform parametric analysis of different duct profiles and propeller combinations; and as agreed at the Propulsion Working Group meeting in April 2006, the analysis has also included KORT's own design of duct and propeller.

The analyses carried out to date, using UPCA'91, have indicated that aft-flared ducts, of the sort required for swirl-jet production in a ducted propeller device, can display some attractive performance gains, but may be subject to separation phenomena. However, because UPCA'91 is an inviscid code, with empirical viscous correction, it has certain limitations particularly with regard to modelling flows undergoing separation. It was, therefore, decided to continue the duct analysis using a separate RANS code.

The effects of separation on 2-D duct sections have been investigated using FLUENT in order to provide accurate lift and drag values for ducts with highly flared aft nozzles. These results can then be used to modify the output from the UPCA'91 ducted-propeller software.

With the ultimate purpose of simulating swirl-jet propulsion, using a full viscous formulation, a known experiment published in the Journal of Fluid Mechanics – where swirling flow underwent conical breakdown – has been recreated in FLUENT. This is to verify that the software is indeed capable of accurately modelling conical breakdown in swirling flow; which has since been shown to be the case.

A number of reports have been prepared by UNEW describing the work carried out to-date on workpackage WP 8vp, which are available for viewing on the project website. These reports will eventually be consolidated into deliverable D6.

# 5.0 CONSORTIUM MANAGEMENT

## 5.1 Project Management (Co-ordination)

The basic tasks required of the Co-ordinator, in terms of overall project co-ordination were set out in detail in the Description of Work and it is not proposed to repeat this description here. However, it is proposed to address criticisms, which have been levelled at the Co-ordinator and issues that might be seen as non-compliance in respect of good Co-ordinator practice.

These criticisms centre around: the infrequency of project meetings, the inadequate level of communication by the Co-ordinator and the insufficient liaison with the RTDs on the part of the lead SME's. They were voiced by individual participants, who attended the second project meeting, in London; although it was evident that these reflected collective concerns that had been building up for some time. In order for the EC to see that the project takes these issues seriously, and is prepared to act on these criticisms, the agreed minutes of the second project meeting, and the actions arising, are posted on the project website.

In order to ensure that project meetings take place at frequent and regular intervals during the second half of the project, meeting dates and venues were agreed at the 4-5th December 2006 meeting and will be adhered to. The meeting dates and locations are set out in the revised Project Plan. Any key participant(s) not able to attend will either provide a written report or statement of concerns to be raised by the meeting chairperson, or will elect to have their interests represent by another attending participant.

By way of rectifying the shortcomings in communication and liaison, both SILT and KORT have resolved to have more regular meetings and to stay more closely in contact by telephone to discuss progress on the project. If there are issues raised by any of the other participants that need urgent attention or a rapid response and one is not able to respond, then the other will.

The perception that HTS has not been ‘pulling its weight’ on the project will be resolved by Mr Brotski’s return to the project following his accident. The question of a budget reallocation so that HTS, in effect, recompenses UMA for additional work has already been discussed with HTS and will be resolved before the next project meeting.

KORT is aware that in addition to the aforementioned criticisms, the EC are concerned about the overall co-ordination of the project not being ‘up to scratch’, and particularly in delays to the timely provision of deliverables and reports. KORT can only apologise for this and has resolved to rectify the situation for the remainder of the project. Being totally new to FP6 projects and the role of co-ordinator, KORT has found it difficult to maintain a tight rein on such a multi-discipline trans-European project.

In order to provide closer technical/managerial oversight of the project, Professor Mehmet Atlar of Newcastle University has also agreed to act in a peer review role and to represent the collective interests of the RTD Performers. Based on his knowledge of European projects and the way they should be run, it is hoped that this will instil a more rigorous approach to the coordination of the Swirl-jet project.

## 5.2 Project Management (Project Technical Management)

Project technical management is part of the overall management of the project and falls equally to the lead SMEs and the RTDs. Again a detailed description of this activity is provided in the Description of Work and it is not proposed to repeat this description here. Rather, what is reported here is the way that project technical management has deviated from that intended, both intentionally and to some extent unintentionally, and what steps have and are being taken to try to keep the project on a sound technical footing.

The technical and personnel difficulties that the project has faced during its first year, as set out earlier, have impacted adversely on the technical management side of the project. Although initially, attempts were made to keep to the project plan and the workpackage schedule, it became evident that this adherence to the original plan was not going to be possible through the whole project.

Therefore, in addition to the extension of the project from 18 months to 2 years, the plan is to make application to the EC for the programme of work to be revised to reflect both the changes that have had to be made during this first reporting period and the changes that will be needed to complete the project. A revised Description of Work will be prepared that will address these issues for the whole project.

### 5.3 Project Technical Review

This was an activity seen as being undertaken by each of the project technical managers on a regular basis, with reports being prepared for presentation at the 2-3monthly technical review meetings according to participants' input to each active workpackage. Such reports have indeed been presented at the two project meetings, and have provided a valuable basis for discussion about technical as well as financial issues, collectively, by the project team. However, as already acknowledged the number of project meetings has been insufficient to meet the changing demands of the project and the ad hoc reports prepared by individual participants to try and communicate information amongst the project team have not always elicited the same amount of feed-back as would have been the case had the information been communicated at a group meeting.

With the planned implementation of regular scheduled meetings through the second half of the project it is anticipated that this particular problem will be resolved.

## 6.0 OTHER ISSUES

At the present stage in the project, only the lead SMEs (KORT, SILT and HTS) and the RTD Performers (INSEAN, UNEW, UMA and USE) have made a significant contribution to the project. This was as anticipated, however, since the input of the other SMEs, End Users and ULE is programmed to occur mainly in the second half of the project. Having said that, INTPA (as an End-User) made a very important contribution at the first project meeting in respect of a possible application for the underwater cleaning swirl nozzle.

It will be appreciated from the foregoing descriptions of work performed by the project team that a considerable amount of interaction is taking place between the project participants. Despite the divisions and tensions within the project, these have not detracted from the willingness of individual participants to take an interest in and assist the work of fellow participants on the project.

This interaction between participants stems from two main factors:

- A genuine desire by all to see the whole project reach a successful conclusion
- An innate scientific curiosity, which means that all participants are interested in what their fellow participants are doing.

The latter results from the fact that within the project there are many areas of overlap in the way that the scientific research is being carried out. For instance, both UNEW and UMA are using FLUENT software to model flow behaviour. FLUENT is a powerful code, but requires considerable scientific finesse to obtain the best results. Thus these two participants have interacted to help one another obtain a better output. In the same way, UMA, UNEW and INSEAN use PIV and LVF techniques for flow measurement and flow visualisation. INSEAN is a European (if not world) leader in these techniques and has been able to offer useful advice to the other two participants.

In addition, it is not common practise on the part of marine engineers to consider propeller jets as complex vortical flows, but rather to see the behaviour of propeller jets (including those from ducted-propellers) purely in terms of propulsion performance characteristics. It is evident, however, that despite some unique features, propeller jets can be likened to other vortex jets, and their complex behaviour has parallels in other fields of swirling-jet study. Thus UMA, INSEAN and to a certain extent UNEW have been drawn closer together through this commonality of research interest.

The project is also helping the SMEs to become more scientifically aware, and at the same time helping the RTDs to become more appreciative of their role in furthering commercial applications. As an example of this integration of science and commerce, SILT and UMA have agreed to continue working together on a further project to look at the sediment transport aspects of seabed excavation by swirling jets. UMA is currently seeking funding for this project.

It is also very evident that the three lead SMEs have very limited resources compared to the RTD Performers, and even compared to the other SMEs and End-User participants. This is a constraint for the project, which the three lead SMEs are seeking to overcome by pooling their resources. The loss of a key person in HTS has, nevertheless, left this resource pool somewhat depleted.

It has meant on occasion that the RTDs have had to take the initiative with regard to certain activities or decisions. Also, SILT has been forced to help HTS, and KORT and SILT have on occasion been forced to help one another. These situations may on the one hand appear to reflect weaknesses on the part of the individual lead SMEs; they do, on the other hand, also highlight the strengths of the project as a whole and the generally good working relationship which exists amongst the participants.

There have been no Consortium Agreement or legal issues that have affected the project during the first 12 months.

## 8.0 DISSEMINATION OF KNOWLEDGE

It is a requirement of the project that by the mid-point a detailed plan for the dissemination of knowledge would be prepared The plan is presented here in interim form, because further knowledge is expected to be generated, which may alter the final content and implementation of the plan. The aim is thus to update the plan during the course of the second half of the project.

The plan is sub-divided into three sections, which deal with: 1) exploitable knowledge and its use, 2) dissemination of knowledge and 3) publishable results.

### 7.1 Exploitable Knowledge and its Uses

The following table presents an overview of what are currently considered to be the potential exploitable results. They represent the three application areas of the project.

| Exploitable Knowledge | Exploitable products or measures | Sectors of application | Timetable for commercial use | Patents or other IPR protection | Owner & Other Partners involved |
|---|---|---|---|---|---|
| New highly-efficient means of seabed excavation | A ducted-propeller seabed excavation device | Dredging | 2007-2008 | An additional patent is planned for late 2007 | SILT (owner) |
| New method of underwater cleaning | A diver-held and also a multi-headed cleaning device | Marine engineering and shipping | 2008 | An additional patent is planned for late 2007 | HTS/SILT (joint owners) |
| A more efficient means of ducted-propeller propulsion | A vessel propulsion ducted-propeller device | Shipping and vessel propulsion | 2008 | | KORT (owner) UNEW (licensee) |

#### 7.1.1 New Highly-Efficient Means of Seabed Excavation

For the past 10years SILT have been operating a ducted-propeller jetting system for seabed excavation. The system works by creating a jet of water, by means of a propeller rotating inside a vertical duct. The duct is suspended from a surface vessel capable of moving the duct slowly across the bed, with the duct maintained at a certain height above the bed. The jet created by the propeller is used to scour the bed and depending on the nature of the bed the jet appears to have two quite different modes of operation.

Under normal circumstances the jet tends to make holes in the bed and deposit the excavated material locally around the excavation site – this is ideal for pipeline and cable trenching, but it is of little use for large-scale bed-levelling.

Under certain circumstances it has been noticed that the jet will excavate very rapidly over a large area, causing the material to self-transport over long distances close to the bed. In this mode the equipment is ideal for bed-levelling (dredging) purposes. Hitherto, however, this mode of operation has only been evidenced where the bed is composed of clay or silt. It will occur in sand but only if the equipment has first been operating in a clay area or if clay and sand occur inter-bedded.

The equipment has a proven commercial potential, which has already been demonstrated to the US Army Corps of Engineers (the main dredging agency in America), but there is currently no way of controlling the behaviour of the jet – only nature has this control.

The purpose of the project is to understand how the normal ducted-propeller jet evolves into the enhanced excavation jet and what steps need to be taken to force this mode of operation at the duct outlet.

The innovation characterising this system, which sets it apart from other underwater jetting systems, has to do with the fact that the jet emerging from the duct has a component of swirl imparted by the propeller. Note that the propeller is located at the bottom end of the duct, so it is the raw jet from the propeller that is utilised. Swirl not only adds an additional component of kinetic energy but it imbues the jet with a capacity to change form. By this is meant that the axial and swirl flow components can become concentrated in certain parts of the jet. If these parts are also the ones that impinge directly against the bed, the bed can be subject to very much higher erosive action than would be the case with just the mean flow velocity. Bed erosion (scour) tends to increase as a higher power of the near-surface velocity.

The equipment in its present form has the benefit of being relatively compact and light-weight so that it can be operated from small non-dedicated vessels. This means that anyone with a suitable vessel using this equipment can become a dredging operator.

At present SILT is the sole owner of the knowledge associated with this innovation and it has a number of existing patents that cover the basic ducted-propeller jetting equipment. It sees the potential commercial value of the system, but recognises that the full commercial potential will only be realised once the behaviour of the jet has been brought under control. It is the purpose of the project to provide the necessary understanding, to be able to exercise control over the jet.

ABPMER has expressed an interest in the technology, since not only does its parent company operate dredgers, but they also have a significant maintenance-dredging requirement in order to maintain access to their ports.

The system is easy to operate, but requires an understanding about the geotechnical properties and erodibility of seabed soils, it also requires an understanding about the movement and ultimate fate of the excavated materials. There are environmental issues associated with this type of operation, although these are no more onerous than those which apply to conventional dredging techniques.

SILT would like to see the system being commercially marketed on a franchise basis, empowering small vessel operators with the capability to undertake small bed-levelling (dredging) projects. This has the potential to significantly benefit small ports around the world, which do not have the financial resources to carry out as much maintenance-dredging as they would wish. HTC has expressed an interest in operating the system in this way and has already gained experience with the system, having provided vessels for several trials already carried out by SILT in the Dee Estuary. It is also planned that HTC will be involved in further trials to be undertaken as part of the project. Since SILT does not have the capability to operate the equipment on its own, the franchise route would offer a means for SILT to develop a commercial business operation based around leasing the equipment and providing advice on its operation.

Understanding the excavation processes associated with the swirling jet and the onward movement of the excavated material is particularly important with this technique because there is no removal of seabed material as there is with dredging, where material is removed in a hopper barge, or through a floating pipeline, to a distance point of disposal. ULE will, as part of this project, carry out a certain amount of investigation of this aspect, but only to the extent of examining the influencing of swirling-jets on seabed excavation and the method by which excavated sediment is transported close to the bed. ABPMER are able to assist in this area with the environmental issues associated with this form of bed-levelling.

ULE has expressed an interest in being involved in further laboratory and possible field studies. UMA is currently looking at funding for a subsequent project that will research the numerical modelling of seabed excavation and sediment transport by impinging swirling jets.

Provided that the characteristics of the enhanced excavation jet can be defined and a means found for forcing this jet at the duct outlet; and subject to a successful outcome of the proving field trials that are planned during the second half of the project, SILT (and its associated RTD partners) will look to extend the patent coverage to include any new nozzle geometry. SILT already has patent coverage of the basic operating system.

#### 7.1.2 New method of underwater cleaning

It is evident that if the enhanced excavation jet works so effectively for seabed excavation and the same type jet can be synthesised by a different means, e.g. using a static swirl nozzle, then the same impingement excavation processes can be used for other applications. Thus underwater cleaning is seen as a natural spin-off application for this type of swirling jet technology.

In this case the jet is somewhat smaller and the mean jet velocity is somewhat higher, but essentially the same jet characteristics are required – i.e. a jet containing areas of concentrated kinetic energy, which are caused to impinge on the surface to be cleaned. Onward transport of the eroded material is less important in this instance, although the material needs to be carried away from the impingement site.

It is envisaged that the first commercial prototype of the underwater cleaning application will be a single swirl-nozzle attached to the end of a jetting lance that will be diver-operated. It will be used for cleaning small areas underwater that are otherwise difficult to clean. Cleaning in this respect refers to the removal of biofouling, which is a particular problem on ships' hulls and propellers, and around underwater intakes.

If the single nozzle can be shown to have commercial benefits, consideration will be given to developing a multi-nozzle arrangement that can be used for cleaning larger areas.

HTS is likely to be the main beneficiary of this technology since it already has an established business developing and marketing high-pressure jetting equipment to the maritime and shipping industries. It also has jetting lances designed for underwater usage.

The marketing of an individual swirl-nozzle could, if it proves to be a commercial success, greatly enhance the fortunes of a small company like HTS. However, because of the limited area that a diver-operated single-nozzle can cover, the penetration of this technology will be essentially into a niche market. By the same token, a single-nozzle is unlikely to raise serious environmental issues to do with cleaning of anti-fouling (biocide-containing) coatings.

It is envisaged, however, that if the technology proves an effective and efficient means for cleaning surfaces coated with foul-release paints, a wider-area cleaning system might be developed. The need for such a cleaning system stems from the fact that foul-release paints work on a non-stick principle: they do not contain biocides (so there are no environmental issues) but biofouling can still adhere to these surfaces if the vessel speed or frequency of vessel transit falls below the threshold for self-cleaning. It is thus easier to remove biofouling from these surfaces using water jets, but the surface is susceptible to damage by impact or scoring by hard sharp objects such as barnacle plates. It is thought that a swirling-jet might offer significant advantages over normal water-jets and/or conventional (rotating brush) cleaning methods.

A wide-area cleaning system using swirling jets might thus consist of a multi-nozzle jetting arrangement, perhaps on some remotely operated vehicle (ROV) system able to glide across the ship's hull surface. Or it might comprise a variant on the ducted-propeller set-up used for seabed excavation, where a single duct is mounted on an articulating arm, which maintains the duct nozzle at a fixed distance from the hull surface. It is believed to be a feature of the enhanced excavation jet that impingement creates very little thrust reaction, because vortex breakdown at the surface causes jet momentum to be deflected sideways.

Development of the latter application would necessarily have to extend beyond the present project, and would clearly be predicated on a successful outcome to the single-nozzle development. Hence it is seen as a potential spin-off from the Swirl-jet study.

INTPA has a vested interest in this application, being a developer and manufacturer of both anti-fouling and foul-release coatings. UNEW has an interest in the future development of any wide-area cleaning system, being a leader in underwater robotics. UMA has an interest from the point of view of swirling-jet impingement processes. SILT has an interest on two counts: it has an existing patent that covers the design of the basic single swirl-nozzle, it also has a patent that covers the use of its ducted-propeller system for underwater (ships hull) cleaning. HTC carry out vessel support and servicing activities and might well look to get involved in the application of this technology. HTS has high-pressure pumps that might be used for a multi-nozzle cleaning system.

It is anticipated that an additional patent would be required to cover the specific swirl-nozzle geometry associated with production of the enhanced excavation/cleaning jet. This would be to protect the intellectual property stemming directly from the Swirl-jet project. Further patents would, undoubtedly, be required to cover any subsequent wider-area jetting systems.

### 7.1.3 A more efficient means of ducted propeller propulsion

At the present time it is difficult to see the outcome of the vessel propulsion research producing any novel propulsion means that would be patentable. The research is currently concentrating on looking at existing ducted-propeller propulsor designs and in particularly at KORT's own system, with a view to achieving enhanced performance.

The original Kort-nozzle design is now long out-of-patent and since a wide variety of similar duct and propeller designs are well established in the public domain only very novel designs stand a chance of qualifying for inventive status.

The project has already established that the high-swirl ducted-propeller concept has little or no potential utility. The existing patent that SILT has, covering this application, may thus be of little value either to SILT or to the project.

KORT trades on, amongst other things, its design expertise in the field of vessel propulsion using ducted-propellers. A greater understanding about how the propeller and duct work together to achieve vessel propulsion and the fluid mechanical factors that influence propulsive performance (thrust, torque, free-running speed, etc.), will not only assist KORT in providing a better design service, it may also enable improved performance to be designed into its system. Currently, any changes to the design of the propeller and/or the duct, with a view to improved performance, have to be made on a trial-and-error basis. Full-scale field trials still remain the only way of confirming that a particular design feature will work, because factors other than those relating purely to the duct and propeller influence propulsive performance: the vessel wake field, mechanical linkages, vessel handling, to name but a few. However, numerical modelling and scale model testing can provide valuable insight into the fluid-mechanical processes that ultimately determine propulsive performance.

The potentially exploitable knowledge that is expected to come from the project will thus take the form of design information that will be of value to KORT, but equally could be useful to its competitors. Since this knowledge will be difficult to protect, for reasons already outlined, it is important that nothing is done to release this information into the public domain unless KORT choose to do so.

Since the project has chosen, through the Consortium Agreement, to provide the RTD Performers with access rights to the exploitable knowledge, depending on the utility of the design information and UNEW's input in generating this information, KORT will look to establish some form of licensing agreement with UNEW. UNEW will also have first-refusal on any exploitable knowledge that KORT choose not to develop.

The object is not to prevent publication of basic research by UNEW, but rather to prevent leakage of information that would enable others (external to the project) to commercially benefit, either directly or indirectly, thus jeopardising KORT's monopoly.

At the present time it is difficult to see any direct commercial or non-commercial spin-offs from this particular research application. However, it is possible that if a particular aspect of the research appears to hold out promise for the future, KORT and/or UNEW may look to extend this research via a subsequent project. It is possible that INSEAN may also wish to be involved because of its interest in vessel propulsion.

### 7.2 Dissemination of Knowledge

The purpose of disseminating project knowledge is to promote: knowledge sharing, greater public awareness, transparency and education. How the project has so far sought to achieve this and what it proposes to do for the future, is set out as follows.

The project can be seen as producing two basic forms of knowledge:

- Scientific knowledge generated mainly by the RTD Performers that will be of interest to the wider scientific community.
- Commercial knowledge, based in part on the scientific knowledge and/or its interpretation, which will be of commercial value to the SMEs.

The RTD Performers are keen to communicate the scientific knowledge to advance their standing in the scientific community. The SMEs will, once individual products and services have reached a certain level of development, be keen to communicate the benefits of using these products and services to the wider end-user community.

The project has no wish to unduly delay the publication of scientific information, but it also has a duty to protect the commercial value of this information until such time as it can define and fully protect the latter's intellectual property content.

It was anticipated that by the mid-point in the project the commercial potential of each of the three applications would have started to become evident, so that steps could be taken early in the second half of the project to define what it was that the project was looking to protect. This is just beginning to happen. For the seabed excavation and underwater cleaning applications it stems from basic insight into the fluid mechanical attributes of the enhanced excavation jet, allied to its known seabed excavation commercial potential. For the vessel propulsion application it stems from a deeper understanding about the factors that determine ducted propulsor performance.

However, until the further physical model testing is done to demonstrate improved performance in each of the applications some uncertainty remains regarding the commercial outcome. Thus at the present delicate stage the project needs to be careful about what it says and to whom it says it.

The following overview table defines how the project currently communicates information and how it proposes to do so for the remainder of the project and following completion of the project.

| Planned/ actual dates | Type | Type of audience | Countries addressed | Size of audience | Partner responsible/involved |
|---|---|---|---|---|---|
| Jan 2007 | Project website | Interested 3rd parties, project participants | World wide | Global | KORT |
| Dec 2006 | Direct e- | Targeted individuals | International | International | SILT |

| | | | | | |
|---|---|---|---|---|---|
| | mail | | | | |
| Nov 2007, July 2008 | Conferences | Research/engineering community | International | International | UMA/USE INSEAN/SILT |
| 2008 | Publications | Academia, potential end-users | International | International | KORT |
| 2008 | Workshops | Academia, consultants, end-users | | National, local | KORT |

### 7.2.1 Project Website

The project website was set up in January 2006 and provides the means for communicating information about the project on a global scale, more so than any other form of communication. This is because the internet has the capacity to reach into every home, school, business, university and library - virtually anywhere in the world. A search using the words swirl-and-jet (which are not uncommon words) will lead to the project website, so even if someone is not looking specifically for the site they may well stumble on it by chance. Multiply that chance find by 694 million, which is the number of people estimated to be currently using the internet (see www.comscore.com), and it is evident that the web provides the project with a huge potential audience.

The website has different levels of access rights, so that only non-commercial information is available to out-side parties.

### 7.2.2 Direct e-mail

While the project has considerable intellectual resources it became evident at a very early stage that the project would need to communicate with and try and gain information from the wider scientific community. This makes sense also from an efficiency standpoint in that the project has no wish to re-discover features about swirling jets, or repeat research that others had previously done. Swirling (in the sense of vortex) jets are common to many natural geophysical phenomena (tornadoes, waterspouts, dust devils), industrial processes (swirl combustors, cyclone separators, Rank-Hilsch tubes) and animal locomotion (fish swimming, squid propulsion, bird flight). The scientific community that has build up around the study of vortex flows and jets is thus very diverse and very widely spread.

Communicating with these people provides a valid and extremely effective way for the project to make itself known to the wider scientific community, to identify common areas of interest (methods of investigation, different ways of looking at the same problem, new insights into old science) and at the same time to elicit information that will be of use to the project. It is a form of 'knowledge-trading' based on the free-exchange of information.

The project has a long list of people in universities and commercial organisations around the world with whom it has already communicated and will continue to communicate with. The form of communication is normally by direct e-mail, when at first-contact the person is invited to visit the project website to gain further information about the project. SILT has initiated and maintains this form of communication, for three reasons:

- It set up this line of contact well before the project started in order to overcome its own knowledge deficiency
- It has been found that university researchers are more forthcoming about their research and the research findings when approached by a small commercial organisation than when approached by other university researchers.
- SILT is able to exercise a measure of control over the release of what might be sensitive project information.

#### 7.2.3 Conferences

At the last project meeting the project identified the following conferences at which details of the research might be formally presented:

- Annual Meeting of the American Physical Society www.aps.org - every year this society draws more than 12,000 of the top scientists involved in physics research and education from throughout the world. The next meeting of the Division of Fluid Dynamics is in November 2007, by which time it is considered that details of the UMA and USE research will be in a form suitable for presentation. Abstracts have to be submitted by August and are then published, prior to presentation, in the Bulletin of the American Physical Society (BAPS). This year for the first time BAPS will be freely available on-line. The Society's journal is Physical Review Letters, although authors giving presentations at BAPS are free to publish the whole paper in other journals.
- International Offshore (Ocean) and Polar Engineering Conference and Exhibition. www.isope.org . This annual conference and exhibition provides an international forum where engineers, managers and academia come each year to present and share new challenges and solutions in ocean, offshore and polar engineering. The next suitable meeting is in July 2008, with abstracts being submitted by August 2007. INSEAN consider that this should provide enough time to complete the research and prepare an abstract. Papers are published in the International Journal of Offshore and Polar Engineering.

#### 7.2.4 Workshops

As a platform for presenting both the research findings and the commercial benefits of the three applications, workshops hosted by the End-Users and possibly RTD Performers have been discussed by the project, but not yet fully agreed. The aim would be to attract commercial enterprises, consultants, academics and other potential end-users.

For instance, ABPMER has an interest in dredging development and might host a workshop to publicise the seabed excavation application. UNEW is very well connected in the world of shipping and ship propulsion and might host a workshop to publicise the vessel propulsion application. INTPA has an interest in cleaning of ships' hulls and might host a workshop to publicise the underwater cleaning application.

## 7.3 Publishable Results

As mentioned under conferences, the journals sponsored by the conference host will provide a suitable vehicle for publication in the first instance. It is anticipated that other aspects of the research might well be published in other, yet to be identified, learned journals.

In order to protect the commercial interests of the SMEs the project has agreed that KORT will vet draft publications.