

## The participants in the Wave Dragon project

*In the present phase of the Wave Dragon development project, where a model in scale 1:4.5 is deployed and tested in Nissum Bredning, Denmark in the period 2002 - 2004, the project core group consists of 13 participants from 6 European countries, each serving a specific role in the project work. The large amount of participants is necessary in order to utilise the knowledge spread among European companies and institutes. Below the professional capabilities of the consortium and a short list of tasks to be performed for each participant is given - the company names links to detailed descriptions of the participants in Annex 3.*

[Annex 1:](#) *Previous, ongoing and planned RTD Activities on the Wave Dragon.*

[Annex 2:](#) *References*

[Annex 3:](#) *Description of the participants and "List of Contacts".*

### Wave Dragon Test ApS

Know-how company. Most of the participants in the project have options to be shareholders in this WD development company.

- Evaluation of all test results and inputs to RTD strategy.
- Quality control.
- Overall responsible for dissemination activities and management of knowledge rights.
- Primary responsible partner for technological implementation.

### Löwenmark F.R.I

Danish consultant engineering company, owned by the inventor of the Wave Dragon.

- Design of the Wave Dragon.
- Surveillance and planning in the production and test phases.
- Input to all mathematical modelling and control strategies.
- Evaluation of the test results start the development of a full scale WD prototype.

### SPOK ApS (former EMU)

Project management, environmental impact studies, business development, Construction materials research.

- Day-to-day project monitoring of all activities.
- Market studies with focus on extensive knowledge on the European renewable energy market.
- Feasibility study, including technological risk assessment.
- Input to environmental impact study.
- Overall project management, meeting preparation and progress reporting.

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#### **LÖWENMARK F.R.I**

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Project Manager: H. C. Sørensen

# Wave Dragon Test ApS

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## Balslev A/S

Electrical & automation systems engineering consultancy.

- Design of all electrical systems.
  - Design, implementation, validation and documentation of control-/surveillance-/data systems.
  - Calibration of power take-off system for fixed speed and variable speed turbine operation.

## Armstrong Technology

Naval Architects specialised in design and validation of war ships and Floating Production Offloading and Supply platforms for the oil & gas industry.

- Structural design of the Wave Dragon test rig.
- Analysis of stress & strain data acquired during the tests in Nissum Bredning.
- Input to Environmental Impact study.
- Ship collision risk assessment.
- Life cycle analysis of structural components; assessment on impact on marine flora and fauna.

## ESB International (Ireland)

Power technology consultancy owned by the Irish Electricity Supply Board.

- Evaluation of power quality issues on basis of power monitoring data.
- Investigation of flexible cable solutions from the oil & gas industry with focus on availability.
- Input to market study. The Irish case.
- Input to environmental impact study.
- Cable interference with navigation.
- Life-cycle of electrical components.

## Veteran Kraft AB

Hydro turbine designer.

- Development and design of the Wave Dragon low head axial turbine.
- Responsible for the monitoring and evaluation of long-term turbine performance

## DHI Water & Environment

Wave tank testing, offshore design for oil & gas industry, Computational wave forecasting models.

- Provision of mathematical model for forecasting short-term overtopping on the Wave Dragon.
- Survey of possibilities for utilising wave forecasting tools in the control of the WD freeboard.

## Nöhrind, Research & Development

Market studies, business strategy development and internationalisation.

- Survey of Wave Dragon market prospects for selected European markets.
- Financial risk assessment and more detailed market evaluation of selected cases.
- Analysis of macroeconomic impacts of the technology.
- Dissemination material aimed at financial-commercial audience.

## **MT Højgaard A/S**

International construction enterprise with strong expertise in offshore construction.  
State of the art offshore wind farm construction works experience.

- Project monitoring of the design work.
- Production of the Wave Dragon structure and deployment of the test rig.
- Management and performance of all additional assembly and installation works.
- Construction material strategy and production facility requirements for a full scale WD.

## **Kössler Ges mbH**

Hydro turbine manufacturing

- Manufacturing of the Wave Dragon turbines, excluding runners and hubs.
- Assistance during installation and tests of turbines.

## **Aalborg University (AAU)**

Breakwater structures testing, wave energy testing, wind turbine foundation hydraulic testing.

- Specifications of inputs from measurements equipment to control system.
- Delivery module for automatic adjustment of freeboard height corresponding to the sea states.
- Installation of all measurements equipment.
- Project monitoring of all activities during the construction of the Wave Dragon scale model.
- On-location surveillance of the test rig.
- Verification and calibration of mathematical overtopping model.
- Mathematical short-term timescale modelling off overtopping in cooperation with DHI.
- Overtopping measurements and optimisation and evaluation of freeboard control strategy.
- Stress & strain measurements.
- Scientific dissemination.

## **Technical University Munich (TUM)**

Hydro turbine testing, CFD modelling.

- Provision of automatic turbine control module.
- Manufacturing of turbine runners and hubs delivered to Kössler.
- Calibration of turbines
- Calibration and validation of power simulation software
- Responsible for all turbine regulation tests.

## **Annex 1**

### **Previous, Ongoing and Planned RTD Activities on the Wave Dragon.**

#### **EU Wave Dragon and Related Projects**

JO-ST-3065: Low-pressure Hydro Turbines and Control Equipment for Wave Energy Converters (Wave Dragon).

Exploratory Award, Joule Craft Application & Research Feasibility Study.

Participants: Löwenmark, EMU, Ossberger Turbinenfabrik GmbH, Danish Maritime Institute. (1998)

JOR3-CT98-7027: Low-pressure Hydro Turbines and Control Equipment for Wave Energy Converters (Wave Dragon).

Project accepted for the Joule Craft programme and carried out in the period January 1999-December 2000.

Participants: EMU, Löwenmark, Kössler Ges.m.b.H., Balslev A/S, Belt Electric Aps., Eltra A.m.b.a., Aalborg University, University College Cork, Technical University Munich, Veteran Kraft, Armstrong Technology Ltd. (1999-2000). Also supported by the Danish Wave Energy Program.

NNE5-1999-00438: Establishment of a European Thematic Network on Wave Energy.

Thematic network carried out in the period January 2000- December 2002.

Participants: University College Cork, Rambøll, EMU/SPOK, INETI, Chalmers University, Teamwork Technology bv, Centre for Renewable Energy Studies (CRES), University of Edinburgh, Instituto Superior Technico, Ecole Centrale de Nantes, Hammarlund A Konsult. (2000-2003)

#### **Wave Dragon applications and projects supported by National RTD Programmes:**

##### 1998 - 1999:

Establishing of a model scale 1:50 at DMI. Testing in a wave tank at AAU to establish the hydraulic response, forces in mooring system and energy efficiency. Adjustment of the model and the design parameters.

Sponsor: Danish Energy Agency.

Partners: EMU/SPOK ApS, Löwenmark F.R.I, Danish Maritime Institute.

##### 2000 - 2001:

Re-construction of an existing scale 1:50 model and sequential testing with modifications of the model geometry and mass distribution parameters. Project carried out with support from the Danish Wave Energy Program.

Sponsor: Danish Energy Agency.

Partners: Löwenmark, SPOK ApS, Aalborg University.

## Wave Dragon Test ApS

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### 2000 - 2001:

Development and testing of an axial turbine with variable speed.

Sponsor: Danish Energy Agency.

Participants: Löwenmark F.R.I, SPOK ApS, Veteran Kraft, Technical University Munich, Hällaryd Turbiner AB.

### 2000 - 2000:

Grid connection of an offshore wave energy converter.

Sponsor: Danish Public Service Obligation Program.

Partners: Eltra, Tech-Wise

### 2001 - 2001:

Business plan.

Sponsor: Danish Energy Agency.

Partner: SPOK ApS

### 2001 - 2003:

Establishment of a Scale 1:4.5 model of the Wave Dragon in Nisum Bredning for testing of forces, hydraulic response and overtopping near the Danish Wave Energy Test Site.

Sponsor: Danish Energy Agency.

Partners: Wave Dragon Test ApS, SPOK ApS, Löwenmark F.R.I, MT Hoejgaard A/S, Aalborg University, VeteranKraft AB, Armstrong Technology Ltd., Balslev A/S.

*The Danish Energy Agency project establishes the Test Rig including one existing turbine.*

*The application described below uses this test rig and another 6 turbines are installed, when the DEA test series has been performed.*

*During the time when the DEA test series are performed the remaining 6 turbines are designed and manufactured.*

### 2002 - 2004 – Wave Dragon Application:

Sea Testing and Optimisation of Power Production on a Scale 1:4,5 Test Rig of the Offshore Wave Energy Converter Wave Dragon. The primary objective of the project is to establish the scientific knowledge base needed for deploying a full-scale prototype of the Wave Dragon. This will be obtained through long-term field-testing on a test rig with all systems installed.

The scale model has an installed power of 20 kW corresponding to 4 MW in full-scale with full-turbine deployment. The test program comprises a thorough investigation of turbine control strategies and their implications for power quality and yearly power production.

At the end of the project a production price of 0.11 EUR/kWh is foreseen documented, allowing full-scale prototype demonstration in exposed waters from 2006, which will mark the start-up of commercial exploitation.

Sponsor: Danish Public Service Obligation Program/Venture Company and the EU Energie Program.

Partners: Wave Dragon Test ApS, SPOK ApS, Löwenmark F.R.I, MT Hoejgaard A/S, Aalborg University, VeteranKraft AB, Armstrong Technology Ltd., Balslev A/S, DHI Water & Environment, Kössler Ges.m.b.H., Technical University Munich.

## Annex 2

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## **Annex 3**

### **Description of the participants in the Wave Dragon**

#### **Wave Dragon Test ApS**

Know-how company. Most of the participants in the project are - or shall be - shareholders in this development company for the Wave Dragon wave energy converter. The company is founded on a 50 - 50% basis by Löwenmark F.R.I and HOP holding which again is owned by Erik Friis-Madsen and Hans Chr. Sørensen.

#### **Löwenmark F.R.I**

Danish consultant engineering company, owned by the inventor of the Wave Dragon, M.Sc. Mr. Erik Friis-Madsen. Löwenmark is primarily involved in the design and test phases, evaluating and commenting the findings.

Lowenmark specialises in design and implementation of supply systems, construction technology, installation, and product development.

Erik Friis-Madsen has more than 25 years of experience as consultant engineer, and has performed several projects on energy systems, water supply systems, CHP installations, ventilation systems, and natural gas systems. Furthermore, he has participated in several product development projects within the construction industry.

As inventor of the Wave Dragon, Erik Friis-Madsen is as a key player in the Wave Dragon design and testing phases, securing that the ideas underlying the device design are communicated to the responsible participants, and incorporated properly into the work. Also Erik Friis-Madsen plays an important role in the evaluation of the test results. Previous experiences have clearly demonstrated the value of involving the inventor in most aspects of the project, as he has on several occasions presented novel and practical solutions to experienced problems.

#### **SPOK ApS (former EMU)**

is a consultant company with 6 employees, working with:

1. Consultant assistance in bringing RTD projects towards commercialisation.
2. Speech recognition software
3. Project management within the renewable energy sector.

Dr. Hans Chr. Sørensen member of the Board of the Danish Wind Turbine Owners Association owns SPOK. Dr. Sørensen has more than 25 years of experience with management of international RTD projects, as well as large construction projects, primarily within the renewable energy sector.

Dr. Sørensen has a background in structural engineering, and has a B.Sc. in business management. HOP Holding ApS, which is 100% owned by Dr. Sørensen, controls SPOK ApS.

Among SPOK Consults current assignments the following deserve mention:

- Wave Dragon Market Study. Client: Danish Energy Agency.
- Co-ordinator of the Joule Craft project (JOR3-CT98-7027), Low-pressure turbines and control equipment for wave energy converters (Wave Dragon).

## Wave Dragon Test ApS

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- Co-ordinator for the Manufacturing and deployment of the foundations for the worlds largest offshore wind farm Middelgrunden (40 MW), (Denmark).
- Environmental Impact Study and assistance in the public approval procedure for the establishment of a 40 MW offshore wind farm at Middelgrunden outside Copenhagen.
- Concerted action on Offshore Wind Energy in Europe (NNE5-19999-00562), Work Package leader Task leader: Social acceptance, environmental impact and politics.
- Thematic Network Wave Energy (NNE5-1999-00438), Work Package Leader: Social planning and environmental impact.
- Feasibility study of the establishment of a 30 MW offshore wind farm outside Samsø (Denmark). Client: SEAS
- Consultant for the Danish Wind Turbine Owners Association on the establishment of wind power cooperatives being part of the 750 MW offshore wind farms program in Danish waters e.g. at the Horns Rev and Rødsand, operated by the utilities.

### **Balslev A/S**

is a Danish consulting engineering company, which employs 150 persons of which 120 are engineers and technicians. Balslev is one of the leading Danish consulting companies within all kinds of electrical systems, and delivers complete solutions for the construction, infrastructure, industry, and supply sectors. Balslev has participated in the Wave Dragon Joule Craft Project.

In the Wave Dragon project, the Energy and Automation divisions will be involved, as Balslev will partake the design and purchase of electrical, measurements, grid connection, and regulation systems.

Balslev's has assigned the chief of development division, M.Sc. Henrik Rosenbjerg as project manager for Balslev A/S. Henrik Rosenbjerg has acted as project leader for several international design and development projects, primarily within his technical field of expertise electrical characteristics of materials and cathodic protection. Henrik Rosenbjerg has been heavily involved in drafting safety standards for gas pipelines in the Baltic States, in terms of electrical interference.

Other key persons involved will be head of the Energy Division Senior Engineer Mr. Henning H. Hansen, Chief of the energy division. During the last decade Mr. Henning H. Hansen has been responsible for planning, design, supervision and testing of generator plants. This experience stems from projects within the industrial electronic field, as well as within the field of power systems, ranging from diesel generator sets and converter systems to no-break systems. For several Years Mr. Henning H. Hansen has been involved with design, design checks, field tests and training of local staff related to diesel power stations and rural/urban electrification projects in West Africa.

Finally Senior Engineer André Hermansen from the Automation department, will play an important part in the project, being technically responsible for the design of surveillance, control and data acquisition systems. André Hermansen has 10 years of experience within design and programming of SCADA/PLC systems of various types, primarily within manufacturing industries. André Hermansen has acted as project coordinator for the automation part of several large manufacturing lines, performed throughout most of Europe.

### **Armstrong Technology**

is a British maritime design consultancy with approximately 50 employees, offering technical services on a worldwide basis to the offshore market. The Babcock International Group has recently acquired the company. Armstrong Technology is overall leader of the design phase of the project. Armstrong Technology has participated in the Wave Dragon Joule Craft Project.

Armstrong Technology is internationally renowned for their capabilities in design and development of warships, merchant ships, Floating Production Supply and Offloading Platforms (PPSO) and floating platform technology. The range of services offered by Armstrong Technology includes: Designs for build conversion, project support, system and equipment specifications, tender production and vendor appraisal, platform feasibility and concept studies, structural studies and hydrodynamic analysis, material and labour cost estimates, trials conduct and assessment, build strategies and production planning, shipyard and production facility evaluations.

Armstrong utilises state of the art technologies such as 3D CAD for design, virtual reality software for walk through design evaluation, automatic material list generation, and complex computer modelling systems for structural design and hydraulic response analysis.

Officer in charge for the proposed project will be Technical Director Dr. Graeme Mackie, who has more than 25 years of experience within shipbuilding and naval design as well as research experience within offshore design.

### **ESB International (Ireland)**

is an international engineering, contracting and management consultancy organisation. It operates in the fields of power engineering, power restructuring and reform, privatisation strategy, IPP development, structural and infrastructural engineering, institutional strengthening of transmission and distribution, management consultancy, project and construction management, power systems contracting, financial strategy analysis and asset valuation, institutional development engineering.

With a turnover of \$100 million in 2000, ESB International has more than 800 employees. They are engaged in projects in more than ninety countries in Africa, Asia, Europe, North America and the Middle East. More than two thirds of the staff have professional qualifications from universities or technical colleges in electrical, mechanical and civil engineering, architecture, environment, finance, management, organisational theory, and information technology.

ESBI services include:

- Restructuring of the electricity sector: separation of Distribution, Generation and Transmission companies.
- Setting up new industry structures
- Analysis of management, financial and business changes needed to operate in the new commercial environment.
- Civil, mechanical and electrical engineering services.
- Market sector reform
- HR management issues including change management, manpower planning, training, staffing analysis, downsizing strategy implementation and staff development.
- Tariff analysis including separation of social and commercial issues.
- Analysis of social and environmental aspects of market reform changes, stakeholder briefing, management of staffing issues, and related communications issues.
- Asset valuation and allocation.

The sectors in which ESBI operates are very diverse, ranging from energy, water and environment, to transport, telecommunications, industry and commerce.

Assignments carried out by ESBI have been funded directly by client governments and by international development agencies, including World Bank, United Nations, European Development Fund, Kuwait Fund for Arab Economic Development, Commission of the European Communities, European Investment Bank and European Bank for Reconstruction and Development.

ESBI is a wholly owned subsidiary of ESB, Irelands electricity company. In its Overseas projects ESB International can call on the services of more than 9,000 highly experienced ESB staff across all disciplines – engineers, accountants, IT specialists, HR specialists etc. ESB/ESBI has unrivalled expertise in the Electricity Utility Sector, developed over 70 years of managing all aspects of Irelands Electricity Utility, and over 20 years experience in managing overseas projects.

This experience covers all aspects of power generation (wind, hydro, oil, gas, turbines, peat, coal): electricity distribution at 10kv, 20kv, and 33kv, transmission at 110,220, and 400 KV, and all associated services – IT, Customer Management, Billing, Training, Materials management, Energy management, etc. It also encompasses significant market reform and regulatory expertise.

Within Ireland, ESB provides a reliable and economic electricity supply to 1.5 million industrial, commercial and domestic customers. It has income of US\$1.8 billion and annual sales of electricity are in excess of 15,000 million units.

ESB staff assigned to consultancy projects Overseas are carefully chosen from specialist senior staff who have been with the organisation for many years, have a proven track record of performance within ESB, and have demonstrated their ability and skills in carrying out assignments quickly, efficiently and economically. They also have shown their ability to work in harmony with people and cultures of the countries in which they serve. On average, each of ESB International's staff has more than ten years consultancy experience.

ESB International has assigned Senior engineer in the renewable energy department Pat McCullen as responsible for ESB Internationals involvement in the Wave Dragon project. Pat McCullen has in his Career been involved in engineering design, feasibility studies, safety, quality, construction and project management of major civil engineering projects. Specific assessments include eco-audit of industrial and civil projects and team leader on a range of environmental engineering assignments covering renewable energy and. Pat McCullen is the Irish power industry representative in the European Thematic Network on wave energy, Is responsible for the Irish monitoring programme for wave energy performed for ESB (Irish Utility), and has been responsible for the evaluation of total Irish renewable energy resource and energy price relationships for 2000 and 2020, (wind, hydro, biomass, waste to energy, solar, geothermal, wave and tidal resources) performed for EU DG12 and the Irish Government.

ESB International will call in expertise from the offshore and electrical engineering departments for some of the work tasks to be performed. External assistance for analysis of cable solutions from MCS International, who is an experienced Irish consulting engineering specialised in computational engineering analyses for solutions for the oil & gas industry.

### **Veteran Kraft AB**

is a small Swedish consulting engineering company, which is specialised in designing all aspects of hydro power plants. Assigned to the project is Chief Engineer Prof. Evald Holmen, who has more than 40 years of scientific and practical experience within design of hydro turbines all over the world. Prof. Evald Holmén has been in charge of several large hydropower projects of up to 450 MW size, deployed all over the world. Veteran Kraft has participated in the Wave Dragon Joule Craft Project.

Prof. Evald Holmén has lately designed a state of the art Kaplan turbine in cooperation with Technical University Munich, specially developed for optimising overall efficiency given the low and varying head and flow available at the Wave Dragon. The turbines, which have been tested at the turbine test stand at TU Munich during the previous Joule Craft project, are the same that will be deployed here. In actual operation runner blades and guide vanes will be fixed, to minimise the need for maintenance.

Prof. Holmén has a long relationship to Kössler providing turbine designs for hydropower projects.

### **DHI Water & Environment**

DHI Water & Environment is an independent, international consulting and research organisation affiliated to the Danish Academy of Technical Sciences. The Institute is organised into four divisions: Environmental Technology & Chemistry, Water Resources, Water Environment & Informatics, and Marine Technology. DHI will be represented through the Water Environment & Informatics department. The consulting services are based on the development and application of know-how and advanced technologies within ecology and environmental chemistry, water resources, hydraulic structures and hydrodynamics and other areas related to water environment. DHI offers a wide range of consultancy services, software tools, and physical model testing facilities.<http://www.dhi.dk/AboutDHI/organisationalDiagram.htm> The Institute has a staff of approximately 475, the majority of whom are professional engineers and scientists with post-graduate qualifications and several years of consultancy and R&D experience. Projects have been conducted in more than 140 countries.

Person in charge of the Wave Dragon project activities will Dr. Hemming Schäffer who has a strong international professional reputation within the hydraulic research community, where he has contributed to the theoretical understanding of multidirectional waves. Hemming Schäffer is reviewer for a number of international scientific journals including Journal of Fluid Mechanics, Journal of Geophysical Research, Journal of Waterway, Port, Coastal and Ocean Engineering and has been reviewer for NSF proposal and ISOPE conference papers.

### **Nöhrind, Research & Development**

is a British consulting company specialised in corporate strategy with focus on internationalisation. The company holds more than ten years of experience in the field and has since 1997 focused on working with companies, within the area of environmental and energy technology companies, seeking to expand internationally.

Nöhrind has an extensive network of international and local partners who specialises in market development, hence enabling Nöhrind to work on local terms when building international markets.

### **MT Højgaard A/S**

is one of the largest Danish construction companies with app. 6,000 employees, internationally renown for their vast references from large international construction projects. The company reference includes industrial construction projects, bridge building, tunnel construction and offshore construction.

MT Højgaard have participated in numerous major European construction projects, e.g. construction of a railway tunnel under the Great Belt (Denmark); building of a railway tunnel under Oresund (Denmark/Sweden); Building of Pont de Normandie - a cable-stayed bridge with 856 m main span. Within the renewable energy sector, MT Højgaard are responsible for the construction of the foundations for a Danish 40 MW offshore wind power farm

MT Højgaard have access to all services needed for the proposed project, by incorporating own divisions, but has also access to a large European contractor network, which can be utilised on an ad hoc basis, if perceived necessary.

MT Højgaard's engagement in the proposed project will be led by Senior Engineer Mr. Lasse Loevgreen, head of department for MT Engineering, and responsible for all engineering and tendering activities carried out by the department.

Mr. Loevgreen has throughout his career acquired vast experiences from steering large construction projects. For example his responsibilities for the building of the Great Belt tunnel included planning and co-ordination of all technical matters, and planning and design of temporary works, including a segment factory for producing 62,000 concrete segments for the tunnel lining; a temporary harbour; transport systems, and major civil works for the New Sprogø artificial island

Mr. Loevgreen is member of the Executive Committee (Danish Committee for Codes and Standards), member of the Committee CEN/TC 288 (Technical Committee for European Code of Practice in Geotechnical Constructions), member of the Executive Committee (Danish Institute for Concrete Technology), member of the Board of Directors (Danish Association for Tunnelling and Underground Works), member of the Foundation Code Committee, member of the Committee for Information Technology (Association of Danish Contractors).

### **Kössler Ges mbH**

is an Austrian manufacturer of hydro turbines. Kössler Engineering Works was founded in 1928, and has specialised in producing small and medium sized hydro turbines of the Kaplan, Francis, and Pelton types. Kössler has 78 engineers and technicians employed, and possess its own design and technical development office. Kössler has a strong reputation within Kaplan turbines, which are specially suited for operation when head and flow is low and varying, and has hydro turbines in operation in most parts of the world. Kössler has participated in the Wave Dragon Joule Craft Project.

In charge of the Wave Dragon project will be managing director Mr. Werner Panhauser, who has a background in mechanical engineering, and who has more than 20 years of experience within designing, producing, deploying and maintaining hydro turbines.

Kössler has a long-lasting business relationship to Veteran Kraft, and has previously produced several hydro turbines after Veteran Kraft designs.

### **Aalborg University (AAU)**

Hydraulics and Coastal Engineering Laboratory, Department of Civil Engineering, has for more than 25 years performed research related to wave loads on coastal structures, their structural behaviour and their impact on the environment. Many types of protecting structures including breakwaters have been studied in detail in two and three-dimensional physical models as well as through field tests. Advanced models for wave propagation, sediment transport and spreading pollution (CFD models) are developed and widely used within the laboratory.

During the last four years the field of wave energy has been growing in Denmark, and AAU has had a major involvement in these activities. This has resulted in the development of a world-leading knowledge on design of naval structures for optimal overtopping, and in mathematical modelling of overtopping on floating structures. Aalborg University will be overall leader the test phase of the project. AAU has participated in the Wave Dragon Joule Craft Project.

Staff from Hydraulics and Coastal Engineering Laboratory has been engaged in several Joint European research projects during the latest years, including:

- Monolithic coastal structures (MAST2)
- Rubble Mound Breakwaters (MAST2)
- Berm Breakwaters (MAST2)
- Full-scale dynamic load monitoring of rubble-mound breakwaters (MAST2)
- The optimisation of crest level design of sloping coastal structures through prototype monitoring (MAST3)

- Evaluation of the hydraulic response of the Wave Dragon (Joule Craft)
- Caisson investigations (LIP/MAST/TAW)
- Spatial coherence of impact pressures at a vertical breakwater in multidirectional seas (Training and mobility of researchers programme)

Key personnel from Aalborg University will be associated professor M.Sc. Peter Frigaard, who will be coordinating the research activities. Peter Frigaard has experience from several wave energy studies, including tests of the hydraulic response and mooring forces of the Wave Dragon. Peter Frigaard has also been involved in several international research projects on breakwater monitoring. Aalborg University will assign Dr. Jens Peter Kofoed especially for the Wave Dragon project. Dr. Kofoed has been heavily involved in research on optimising overtopping on naval structures.

### **Technical University Munich (TUM)**

Institute for Hydraulic Machinery and Plants, is a German University. TU Munich will lead turbine performance tests, and participate in the turbine design, based on their previous work on low-head turbine design, and also in the regulation strategy tests and in verification and calibration of the overtopping mathematical model. TUM has participated in the Wave Dragon Joule Craft Project.

The Institute for Hydraulic Machinery and Plants was founded in 1912 in order to provide the scientific support needed for installing hydropower schemes. The institute has therefore more than 90 years of experience within turbine design and testing.

During the last 15 years the Institute for Hydraulic Machinery and Plants has extended the scope of their scientific activities from pumps and water power applications, to all kinds of fluid machinery including water turbines, centrifugal pumps, fans, compressors, torque converters, ship propellers and medical applications. As to the methods employed, the development and application of new numerical flow simulation methods (Computational Fluid Dynamics) has become a major working area besides the experimental flow investigation.

Scientific officer in charge of the Wave Dragonproject will be Dr. Wilfried Knapp, who has more than 15 years of experience in designing, CFD-modelling and practical testing of hydro turbines. Dr. Knapp has recently been involved in the design and testing of a 0.34 mm model turbine of the Kaplan turbine, specifically designed to the operation environment at the Wave Dragon.

Furthermore, the scientific staffs of the Institute is frequently used by turbine manufacturers for testing of model turbines, prior to full-scale deployment (which is the normal practise within the industry), as the institute possesses a state of the art turbine test stand.

