Underwater Systems and Technologies – current state and future developments

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Abstract:

The paper gives an ovierview of current state and future trends of underwater systems and technologies. Market drivers for this technology is presented. Description of underwater systems and technologies especially remotely operated underwater vehicles and autonomous underwater vehicles was given. Achievements of the Laboratory for Underwater Systems and Technologies were described. Future research and development challenges were shortly presented.

1 Introduction

Developments made in UUV s and related technologies have enabled UUVs to move out of the research laboratory and into commercial, military, and scientific areas, [1,2].

The commercial use of UUVs centers mainly on the gas and oil industry. Here UUVs are used for inspection, maintenance and repair (IMR). High resolution seabed mapping and imaging for commercial mapping and oil/gas pipeline surveying in shallow and deep waters are major tasks done for the oil and gas industry. The fact is that the only human-made infrastructures at deep seabed, designed and capable to operate for periods of 20 years, are production platforms and sub-sea production systems (wellheads, manifolds etc).

Military use of UUVs focuses on surveillance, minesweeping and mine countermeasure work. Maritime security of ports and sailing routes have today high priority and is defined by the IMO ISPS code. Lately use of UUVs is present in aquaculture (fish farming) where ROVs are used for net cleaning of fish farm and AUVs for feeding fish in the open sea, [5]. The scientific community continues to make advancements in UUVs usage. Use of AUV s and ROV s for high-resolution mapping of the deep ocean floor, as well as mapping salinity, temperature, oxygen, fluorescence, backscatter and pH over a full annual cycle is very common. AUVs and ROVs are used under the ice in the Arctic for the purpose of monitoring the influences on climate change. Quantitative survey of hydrothermal plumes and other near-bottom surveys in rugged seafloor terrain is going on today on a yearly basis. The usage and capabilities of AUVs and ROVs will continue to grow.

UUVs - Unmanned Underwater Vehicles.

AUVs - Autonomous Underwater Vehicles.

ROVs - Remotely Operated Vehicles.

2 Market drivers

The following is a short summary of recent market research, in the public domain, that has been undertaken in this subject areas. As a main market drivers for underwater systems and technologies three main areas can be identified. These are offshore oil/gas production, military needs and scientific research.

2.1 Market driver – offshore industry

When the offshore production is analyzed a major problem that can be immediately identified is that the offshore shallow water production is in long-term decline (see Figures 1a and 1b).

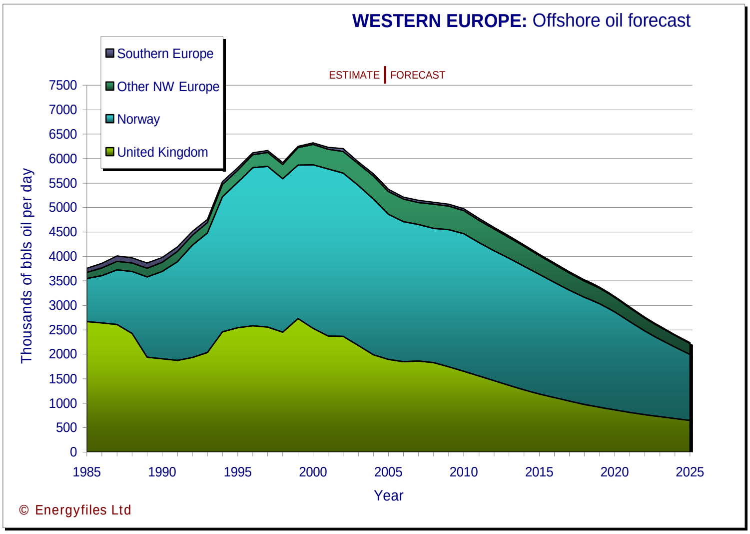

Figure 1a: Shallow water offshore production forecast

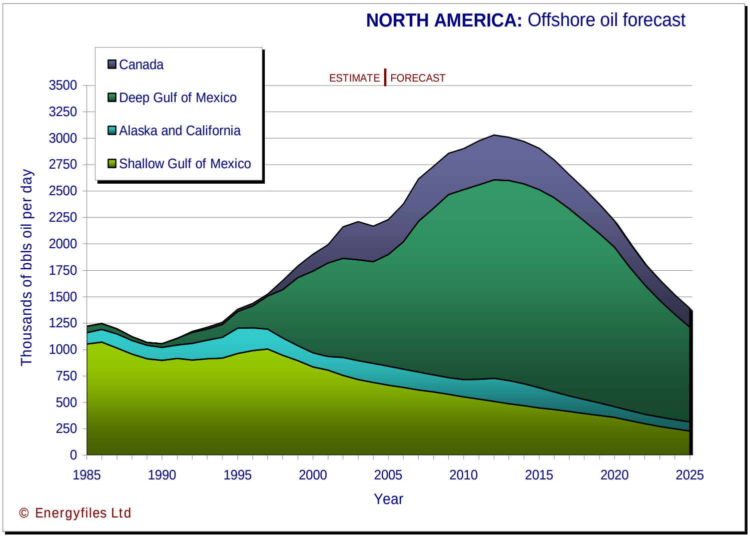

Figure 1b: Deep water offshore production forecast

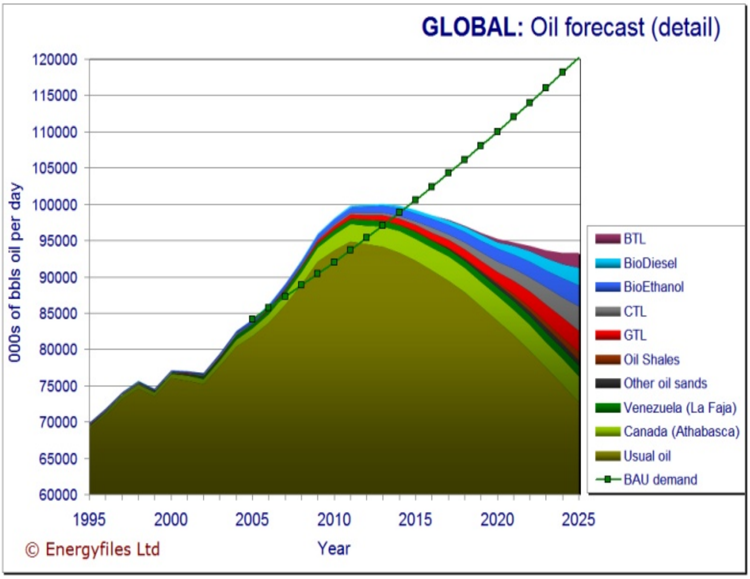

Figure 2: Global production of oil with demand forecast

Source: "The World Offshore Oil & Gas Forecast", Douglas-Westwood Ltd.

Due to the fact that demand for oil will in the future become enormous (EIA forecast 118 million barrels per day by 2030) we will sooner or later reach the point of higher demand than supply. In Figure 2 it is shown that this point we should expect around 2014 ([3], Source Douglas-Westwood Ltd.).

2.2 Offshore engineering in deep waters

For the offshore production in deep waters that are not reachable by divers, the only possibility for IRM is to use ROVs or AUVs. Today the World largest deep offshore oil field is in West Africa (Girasol) at depth of 1350 m (see Figure 3.)

IRM - Inspection, Repair and Maintenance

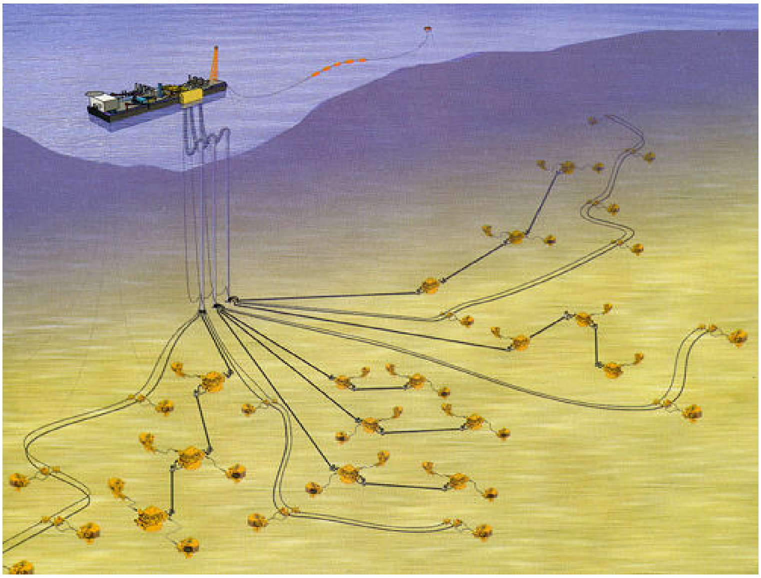

Figure 3: Deep offshore oil-field.

Girassol (West Africa), Field dimensions: 14 x 10 kilometers

Development plan: 39 subsea wells, including 23 producers, 45 kilometers of flowlines, 29 kilometers of injection lines and 70 kilometers of umbilicals

Peak production: 200,000 barrels per day

The depths that are lately becoming interesting for the oil industry is ~2000 m. We will see in the future offshore production approaching depths of 3000 m. The concept of “deep sea” differs from scientific and commercial community – see the Table 1.

Table 1: The concept of "deep sea"

	Industry community point of view	***Scientific community point of view***
Definition	"Deep sea" means 1000 to 2000 m "Ultra-deep sea" means 2000 to 3000 m	Deep sea means up to 6000 m, in order to cover the major area of interest."Ultra-deep" is 11000 m
Motivations	Deep sea activities are driven by economical factors (oil price, political and strategical factors)	Study and comprehension of basic local (regional scale) and global phenomena (large/earth scale, such as global climate change, earthquakes, volcanoes, tsunami)
Fields of interest	Basically only oil industry and cable communication companies are involved in deep sea activities. Ocean mining and waste disposal activities are presently in stand-by or in initial phase.	Many disciplines interested in deep sea (physical oceanography, chemical oceanography, biology, seismics, geophysics, etc.) each with different approaches and requirements relevant to observation and acquisition methods.

2.3 Market Driver - maritime security

Maritime security in a more general sense includes the safety and security of:

- Infrastructural objects (civil engineering constructions - bridges, piers, marinas, ...).
- Cultural heritage (underwater arhaeological sites).
- Explosive ordnance disposal (EOD).
- Detection of illegal activities (illicit trafficing of drugs, weapons, ...).
- Protection and monitoring of the aquatorium (fish reserves, ecological state, oceanographic and hydrographic research, quality of water, etc.).

2.4 Market Driver – global warming

Climate change that is evolving lately force us to analyse this change, due to the fact that this process have a global yet unknown consequences. Many current estimates are quite disturbing. Namely, if the Arctic ice mass diminish by 20%, then near surface water temperature will rise for 1 0C and ocean salinity as a consequence will also rise for 1% . What effect will that have nobody knows yet.

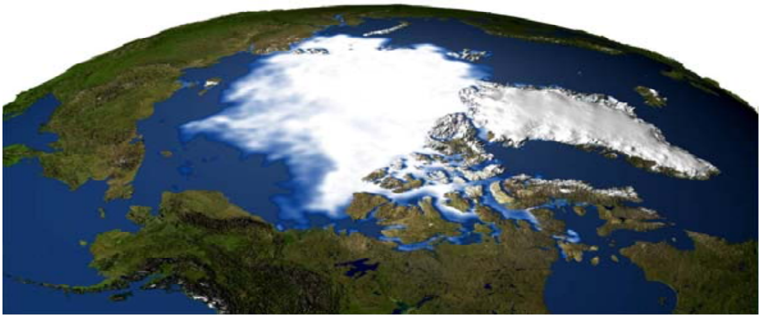

Figure 4: Summer Arctic ice in 1979 and 2000.

(Pictures by NASA Goddard Space Flight Center).

3 Present state of technology – Unmanned Underwater Vehicles

Unmanned underwater vehicles can be categorized to remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). They are characterized with the lack of pilot (man/women) onboard.

3.1 Types of Remotely Operated Vehicles

ROVs has been used for the last 30 years all over the world to get access to under-water locations not easily accessible by divers or by other means. ROVs are under-water vehicles that are tele-operated. An umbilical, or tether, carries power and command and control signals to the vehicle and the status and sensory data back to the operator's console. ROVs can vary in size from small vehicles fitted with one TV camera (used for simple observation), up to complex work systems that can have several dexterous manipulators, video cameras, mechanical tools and other equipment (see Fig.5). They are generally free flying, but some are bottom-founded on tracks. Towed bodies, such as those used to deploy side scan sonar, are not considered ROVs.

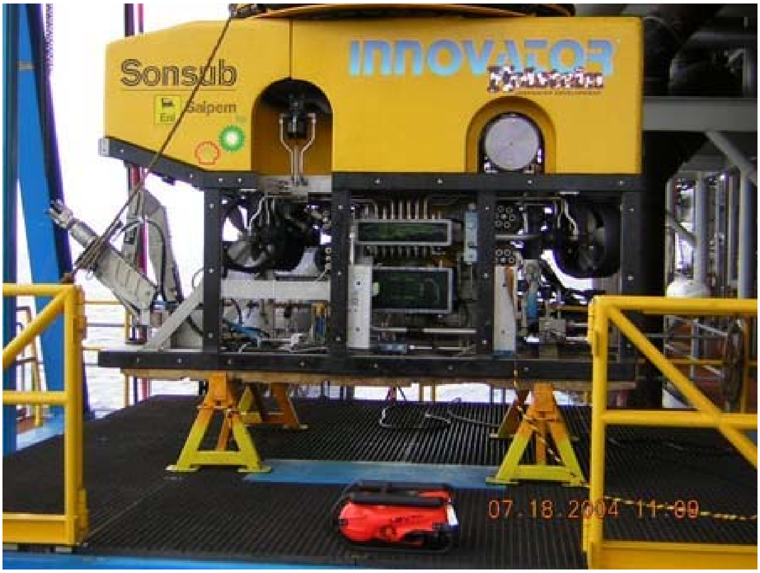

Figure 5: Working class and observation class ROVs

3.1.1 ROV – status and perspectives

ROVs are mature technology suitable to meet all needs of the oil & gas industry (up to 3000 m depth) as well as scientific and military community. New developments in deep water ROVs include: all electric deepwater WorkClass ROVs, reduction of inefficiencies (30% and more), smaller and lighter units, more reliability (less parts), smaller umbilicals, more sophistica-ted tooling and advancement in launch and recovery systems. We can expect more automation to enter ROVs and relieve operators from strain work.

3.2 Autonomous Underwater Vehicles (AUVs)

AUVs are free-swimming, unmanned submersible vehicles, independent of outside facilities or operators. They are capable to fulfill the mission without the help of operators. Present applications include: sub-sea survey; sub-sea inspection; pipeline inspection; cable inspection; oceanographic sampling; environmental monitoring; iceberg profiling; under-ice surveys; mine detection and countermeasures; diver delivery / supply vehicles; downed airplane / shipwreck searches; underwater photography.

3.2.1 AUV – current status

AUV industry has begun to emerge from the R&D and prototype phase to small production runs. Over the past decade, nearly 400 AUVs have been built (mostly experimental). About 30 programs are presently active worldwide.

Scientific community and military were the early adopters. For the oil & gas industry AUVs are becoming efficient tool for seafloor survey and mapping, especially in deepwater (up to 3000m). Cost reduction of up to 30% with better data quality with respect to traditional tools (towfish) should be expected from AUVs. Commercial AUVs services are now offered. However, the costs of AUV operations are still significant.

3.2.2 **Survey AUVs**

Majority of AUVs today are used for the survey and because of that they have slender body similar to torpedos (see Fig. 6).

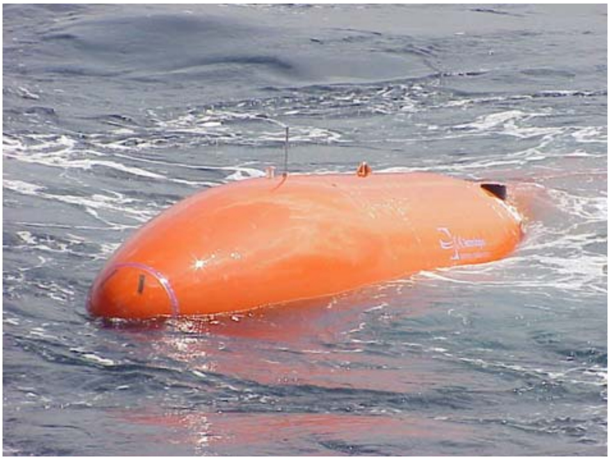

Figure 6: Hugin AUV by Kongsberg

3.2.3 **Future of AUVs**

Typical endurance of commercially operated AUVs is up to 70 hours; it will continue to increase as energy storage technology improves. This will allow also for higher speeds, additional sensors and better lighting for underwater video/photography. AUV costs will trend downward. However, low cost AUVs (like low-cost ROVs) will have commensurate limitations in their capabilities. Use of multiple AUVs simultaneously will become practical where projects are significant enough in size to justify the increased investment.

3.2.4 **AUV Market Prospects**

Over 450 AUVs of aproximately 110 different models have been built to date. Over 900 AUVs will be required over the next 6 years (through 2017) at a cost of some $1.8 billion. AUVs now have the potential to change the game in many areas of underwater operations. AUVs offer a great increase in cost effectiveness for the military and financial leverage for all sectors. Market drivers for AUVs are: war on terror – a need of AUVs in mine counter measures and security work. Depletion of shallow water offshore oil & gas reserves of the North Sea and Gulf of Mexico has forced companies to move into deep waters and seeking new technologies. AUVs are now in demand for mapping the deep seabed for deep water oil explorations. Among research community the need to understand the role of the oceans in the climate change has ignited a massive growth in demand for underwater systems.

3.2.5 AUV – key technological requirements for sub-sea intervention

We need key technological requirements for sub-sea intervention with AUVs. Real-time data at the surface - ideally real-time acoustic command and control. More power to operate tools. Ability to hover with capability of physical interaction with the working environment. Simpler launch and recovery. Smaller size of systems i.e. AUVs should not be larger than the existing ROV package. New layout and design of sub-sea facilities.

3.2.6 Towards an intervention-class AUV

Present AUV concept (survey-class) cannot have a role in Inspection, Repair and Maintenance (IRM) activities for oil & gas offshore industry. To make AUV suitable to carry out intervention tasks on sub-sea facilities it is necessary to:

- Combine ROV and AUV capabilities (hybrid AUV/ROV).
- Develop a completely new configuration of AUV, different from the survey-class AUV: the intervention (or work class) AUV.

3.2.7 Hybrid AUV/ROV – status and perspectives

Hybrid AUV/ROV consists of the large single-purpose autonomous shuttle carrying a work class ROV . The sub-sea facility to be serviced is provided with a dock/connection port (power/signals/video). The system may be deployed from a permanent surface facility (e.g. FPSO) or a simple craft of opportunity such as an anchor handling tug. The hybrid solution could be difficult to apply on large developments (such as Girassol oil field). Namely, there would have to be docking stations scattered all over the field with the associated cost and technical implications. The power and control problems are mainly solved for this type of systems. Operational capability is limited by the length of ROV umbilical and the docking/connection system must be: fail-safe; serviceable and replaceable in case of failures. At present we can say that hybrid AUV/ROV status is still more like a technological demonstrator.

Figure 7: Example of a hybrid AUV/ROVs Swimmer (by Cybernetix).

3.2.8 **Intervention AUV**

Intervention AUV is a multi-purpose AUV fitted with manipulators and operated in acustically-supervised mode. Intervention AUV is able to dock to the infrastructure and interact with it. This type of AUVs is designed primarily for use in oil/gas offshore industry (see Fig.8).

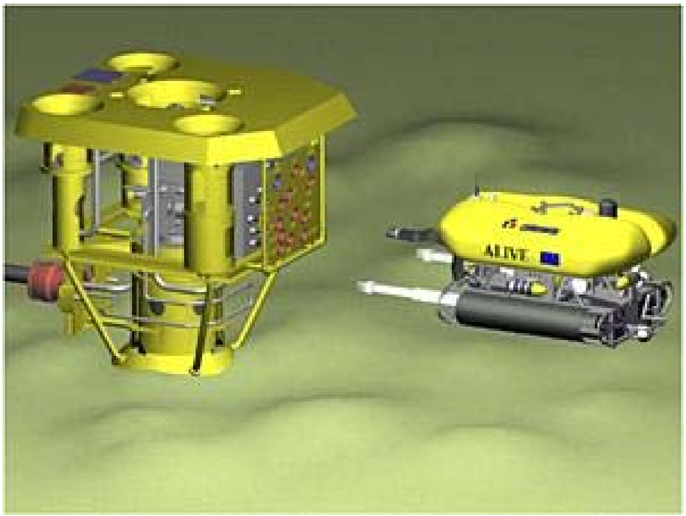

Figure 8: Intervention AUV Alive (by Cybernetics).

3.2.9 Intervention AUV – status and perspectives

This is a promising technology. Case studies [4], indicate that use of AUV technology instead of ROV for IMR applications could entail savings in the order of 50%. Power represents the main limitation. Their present status: technological demonstrator.

3.3 Future underwater systems/requirements

Current point-to-point acoustic links will be replaced in the near future with autonomous networks for ocean observation. Future networks will consist of ad hoc deployable sensor networks and autonomous fleets of cooperating AUVs (see Fig.9).

This networks will change type of nodes from present day fixed and static to future dynamic and mobile (sensors, relays, gateways). These systems will use different types of signals and system requirements: low/high rate (~100 bps-100 kbps); real-time/non real-time; high/moderate reliability. It is expected that quite original and new quality of service with this type of systems will evolve in the future. Many research laboratories and groups are at present investigating problems related with cooperative underwater vehicles. The notion of intelligence will have a great impact for this type of systems, and we should expect original solutions in the near future here.

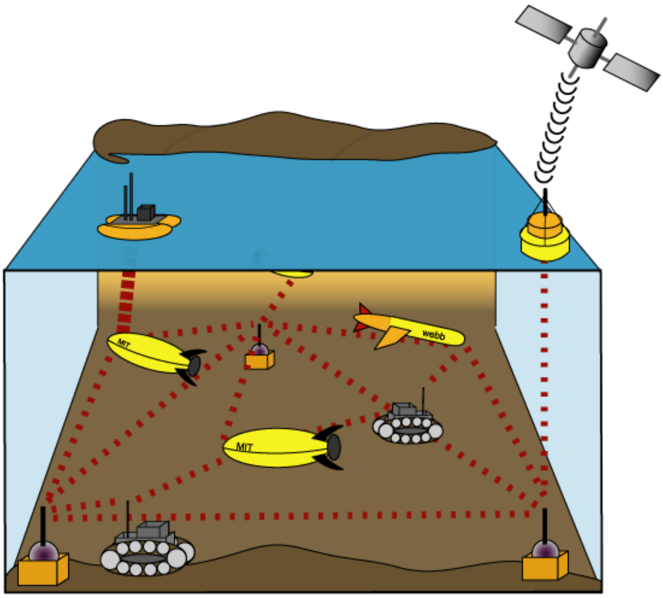

Figure 9: MIT concept of cooperating AUVs

4 Laboratory for underwater systems and technologies - LABUST

Laboratory was established with the goals of:

- R & D of underwater systems and technologies,
- Education in the domain of navigation, guidance and control of unmanned marine vessels (surface and underwater),
- Interdisciplinary and multidisciplinary cooperation for the purpose of underwater systems and technologies,
- Inovation and promotion of high technology in sustainable development and exploitation of the sea, sub-sea, rivers, lakes, technical waters, water reservoirs as well as in maritime security.
- Involving students, experts, researchers and scientists into interdsciplinary domain of high technology sustainable development in underwater areas.

LABUST memberships: Laboratory was a „light member″ of the FP7 Network of Excellence (NoE) HYCON (http://www.ist-hycon.org/) 2007-2009 and is at present HYCON2

Research programmes and projects:

- „Cooperative Autonomous Robotic Towing system“ (CART) - FP7 project for 2011-2013;
- „Breaking the surface“ (BtS) 2012-2014 poject supported by the Office of Naval Research Global.
- „Developing Croatian Underwater Robotics Research Potential“ (CURE) - FP7 project for 2009-2012; http://cure.fer.hr ;
- „Analysis of new potentialities in the synergic management of different underwater robotics devices” - Italy-Croatia bilateral research project for 2009-2010;
- „Autonomous naval MCM neutralization“ – research project with NATO Undersea Research Centre (NURC-CMRE) on new conceptual future autonomous mine neutralization system (2010-2012).

LABUST cooperation:

- Long lasting cooperation agreement with Brodarski institute in Zagreb, Croatia.
- Long lasting cooperation agreement with University of Rostock.

- Cooperation agreement with the NATO Undersea Research Centre, LaSpezia, Italy.
- Cooperation agreement with the University of Zadar, Croatia.
- Cooperation with CNR-ISSIA, Genova, Italy.
- Cooperation with Polytechnic University of Marche, Ancona, Italy.
- Cooperation with „Mobile and Marine Robotics Research Centre“, University of Limerick, Ireland
- Cooperation with „Dynamical Systems and Ocean Robotics Lab“, IST-ISR, Lisbon, Portugal.
- Cooperation agreement with Aurora Trust (USA)
- VideoRay LLC. (USA) on development of new components for micro-ROVs.

LABUST references: inspection of hydro-power plant dams in Croatia, Slovenia and Bosnia and Herzegovina; inspection of port of Gruž (Dubrovnik) for unexploded ordnance (subcontracted by „Major and partners“, Zagreb); search and rescue missions (with „Brodarski institut“, Zagreb and Croatian Navy); missions for marine biology/ecology; missions for underwater archaeology, maritime security missions, etc.

More about LABUST activities can be found at the following Web pages: http://labust.fer.hr ; http://cure.fer.hr and http://bts.fer.hr.

5 Conclusions

Underwater systems and technologies have bright prospects in the future. Many possible applications can be identified. Submarine areas are still mainly unexplored areas. We are still not aware of possible state in these areas, and our knowledge will be better 20 years from now. We hardly now what is going on in deep waters. Intelligent underwater systems and technologies will have great impact on how we will in the future use our water resources. 21st century is the century of exploring vast ocean underwater areas. Underwater robotics plays an important role.

6 References

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