WHITE PAPER AP19
MARINE TECHNOLOGIES

EXECUTIVE SUMMARY

The AP “Marine Technologies” conducts fundamental and applied research and technological developments with impact in a sustainable exploitation of the Ocean resources and in the Smart, Safe and Secure operations at sea and is involved to sustain the development of new regulatory frameworks and standards both at EU and International level.

The multi-disciplinary nature of the research challenges in the field of the green, smart, safe and secure exploitation of seas involve many branches of the engineering, such as materials, structures, hydrodynamics, hydroacoustics, electronics and automation, informatics…, and, thus, imply the AP to cluster skills and research infrastructures from different Institutes of the Department of Engineering, ICT and Technologies for Energy and Transportation: the Institute of Marine Engineering (INM) with competences in the area of naval architecture and marine engineering, the Institute of Information Science and Technologies (ISTI) operating in the field of computer science, the Institute for Research on Combustion (IRC) and the Institute for Research on Engines (IM) active in the key chemical and physical processes underlying energy conversion, the Institute for high performance computing and networking (ICAR) operating in the area of intelligent systems with complex functionality and high performance computing and the Advanced Energy Technology Institute (ITAE) active in developing innovative energy processes and technologies.

If the final research and technology targets of the AP "Marine Technologies" find their motivation in the current social and political challenges, the engineering problems worth to be addressed have a multidisciplinary and complex nature as described in the "State of the Art” section. This has pushed the Institutes to work on several topics and to reach significant results which are further detailed in the "Scientific Contribution to the Relevant Area" section. As highlighted above, beside the relevant scientific production, the AP "Marine Technologies" is active in supporting industry needs for edge technological solutions which are described in the "Impact" section. The long-lasting competence and continuous updating in knowledge and research infrastructures allows the AP "Marine Technologies" to be ready for future and, in some sense, visionary challenges as outlined in the "Emerging Research Challenges" section.

1. STATE OF THE ART OF THE RELEVANT SCIENTIFIC AREA

Oceans are increasingly the crossroads of the resources of the Earth both in terms of exploitation and transportation. Globalization and the global growth of the population have given a strong impetus to the centrality of the oceans in the economic and socio-political equilibrium, which however begins to clash with the primary role of the oceans in the eco-system. The request for a lower environmental impact and the improvement in activities related to the sea are the objectives that have guided research and technological development in past decades; more recently, also in consideration of climate change threats and opportunities.

The keywords for the development of maritime technologies have been Safety, Efficiency and Greening. However, it is not possible to reach significant targets (e.g., an efficient circulation of goods) without eliminating bottlenecks that exist in the whole process (e.g., shortening of cargo unloading and loading time requires up-to-date port infrastructures and inland logistics support). Thus, the integration of technological solutions developed in different sectors of maritime engineering becomes a key element: this is called an Integrated Mobility Strategy. This need for integration is also present in engineering activities concerning the exploitation of the ocean resources: the ocean space utilization within a maritime spatial planning includes energy (fossil and renewable sources), fishing, aquaculture and blue-technologies, hard infrastructures and transport services. The concept of greening widens up to sustainability; matching the environmental constraints in marine technology begins with the choice of materials and assembly techniques and ends with disposal and recovery, following the concept of circular economy. The safety concept currently develops beyond the use of accurate and robust predictive models for vehicles or offshore structures; the growth of diagnostics and decision-making processes pushes toward the reduction of the human factor, using unmanned and autonomous systems, typical of robotics. This further underlines the multi-disciplinary character of ocean engineering, more and more developing under ICT paradigms.

The design, development and manufacturing of ship, offshore structures and on-shore installations involves a multi-disciplinary, integrated and highly complex set of processes and tools that embrace the whole product life-cycle. The process comprises many disciplines which depend also on the specific application: materials (material science), structures (theory of construction and structural mechanics), loads and performances (hydrodynamics, maneuvering, seakeeping and propulsion dynamics, station-keeping, control systems…), propulsion systems, energy generation and storage, automation, comfort, safety and security management. The global trend is towards the integration between digital design and digital manufacturing with the aim of improving quality, reducing costs, delays and reworks. The iterative procedure traditionally used in preliminary design is only partially able to consider all these disciplines in a holistic way and include new constraints due to climate change (increasingly harsh environment). Thus, there is a need to adopt knowledge-based strategies of analysis able to develop innovative concept design based on numerical simulations integrated in a multidisciplinary optimization procedure.

The conversion of energy into vehicle motion is a key issue for surface and underwater vessels as well. The objective is to lower the installed power on-board by designing low-resistance hull shapes on one side, to turn the mechanical energy into momentum change as efficiently as possible with propellers, waterjets, sails. The way this energy is produced makes the difference in classifying a vehicle as environmental friendly since ship exhaust emission causes environmental pollution, greenhouse gases and consequent effects on human health. Low carbon technology and ship electrification are alternative approaches to the same target. Decarbonization involves the development of a more efficient and green propulsion and power supply systems to enable navigation in Emission Controlled Areas. Liquefied Natural Gas (LNG) and/or biofuels (biogas, bioethanol) as fuel for efficient gas engines and in integration with Fuel Cell Systems can decrease the emissions of SOx, NOx, CO2 and black carbon and then the ship GHG footprint. The abatement of new target pollutants can be pursued by increasing the cleaning efficiency of the after-treatment units, also with retrofitting. The exploitation of the Waste Heat Recovery solutions is another way for achieving a higher energy efficiency. Concerning ship electrification current targets are related to use hybrid electric systems for inland waterways, fully electric vessels for urban waterborne transport and possibility of electric plug in for ships for switching off engines in harbors.

Reducing the shipping environmental impacts concerns also facing the problems of anthropogenic noise emissions as underwater noise has been included recently within the definition of pollutions. A joint effort between the marine and maritime research community is to define noise limits and dangerous frequency ranges, but at design level this is still an open problem due to limitations both in simulations and field data.

In a different perspective, the power management on-board contributes not only to foster the energy efficiency but also to guarantee the ship safety by powering critical on-board systems for navigation, cargo, weapons, and other operative functions. The Shipboard Power System aims to be self-adaptive and to play a more relevant role for the All Electric Ship, including propulsion.

In a connected and automated world, ship and offshore systems are designed as cluster of interacting subsystems, but at the same time are also the nodes of complex ocean networks. Nowadays, marine and maritime monitoring and surveillance activities are based on a wide availability of multi-sensor data, ranging from satellite data to ground based data, from radar data to the ones acquired by specific vessels. Thus, data interoperability, integration and security are among the main issues in designing Marine Information Systems and other platforms benefiting from ICT topics. As stand-alone systems, the availability of distributed sensing capabilities along with data fusion and machine learning techniques promises to enhance the safety standard on-board, promoting Predictive Maintenance and Damage Identification approaches.

To reduce the human factor in sea accidents, the purpose of operating large unmanned systems like cargos or small-scale passenger vehicles finds in marine robots its precursor. Marine robotics requires the development of new tools, paradigm and methodologies for the autonomous cooperation of heterogeneous robots, even in the presence of manned platforms. Moreover, the complexity and cost of at sea operations and the extension of areas to be explored and surveyed, as well as the needs of persistent monitoring and rapid environmental assessment, require the development and implementation of new operational concepts able to minimize the presence of support vessels in the operational areas and to improve autonomous underwater intervention capabilities introducing topics like cooperative robotics, sensing and perception, navigation, guidance and control, mechatronics and marine IoT.

2. CONTRIBUTION TO THE RELEVANT SCIENTIFIC AREA

Research and development activities within the AP "Marine Technologies" are addressed to four macro-areas including: (i) "Green transportation", (ii) "Smart, Safe and Secure operations at sea", (iii) "Advanced ship design, construction and performance improvement" and (iv) "Automation and connectivity ".

In the context of the eco-sustainability of maritime transportation, research pillars focus on the reduction of the environmental impact of marine vehicles, which comprises the themes of the low emission engines, the waste management and the impact on marine biodiversity, and on the improvement of the energy efficiency in the maritime transportation, which involves the performance improvement of marine vehicles and the processes of energy production, distribution, management and recovery. Technologies for low emission engines are strictly related to the development of environmentally-friendly combustion and catalytic processes (i.e. low temperature Selected Catalytic Reduction, catalytic oxidation, air purification, catalyst poisoning/regeneration), alternative fuels with low carbon and high hydrogen composition, dedicated internal combustion engines fed by natural gas or synthetic natural gas from biomass and waste as well as electric and hybrid propulsion systems targeted to reduce fuel consumption and pollutant emissions and to improve energy efficiency. These solutions are integrated with new technologies for electric and thermal energy production (e.g. fuel cells and reformers, renewable energy sources), thermo-valorization of wastes and biomass (e.g. onboard waste thermal treatment and gas phase waste heat recovery units, waste heat from exhaust recovery for air-conditioning and refrigeration purposes) and innovative on-board energy distribution and management systems. From the hydrodynamic perspective, the efficiency improvement of marine vehicles is related to the theme of the drag reduction, which is pursued through the reduction of the skin friction by water-repellent coatings (Super Hydrophobic Surfaces) and the optimization of the ship/hull/appendage design by the simulation-based optimization procedures in combination with advanced experimental and computational methodologies.
Besides the reduction of greenhouse gas emissions and oil pollution, there is a growing scientific attention into the problem of the underwater noise and its effect on marine mammals. Research programs have been developed and implemented to study the underlying mechanisms of noise generation and propagation from ship and shipping and to find operative and design solutions for mitigating underwater noise pollution without affecting the fuel efficiency of the propulsion systems. Hydroacoustic research is addressed by numerical prediction methods of the underwater noise generated from propellers and multi-body configurations, coupling the Ffowcs-Williams Hawkings (FWH) equation to suitable hydrodynamic simulations and mathematical methods to model and simulate noise propagation in the oceans, such as the Ray Theory. In the field of experimental hydroacoustics, research is mainly focused on unconventional approaches allowing a cost and time effective analysis of the underlying mechanisms of noise generation and propagation through signal conditioning techniques and synchronous near-field and far-field measurements.

Research on "Safe, secure and smart operations" involves the predictive maintenance of marine vehicles and infrastructures to prevent accidents and failures in critical components, the detection of malfunctioning and damages, the integrated control of the traffic including the presence of drifting objects, search and rescue of men lost at sea and the management of incidents and emergencies. The problem of the predictive maintenance is addressed by the accurate and reliable evaluation of critical loads on marine vehicles and infrastructures exposed to the effect of waves and currents under severe sea state conditions or operations, including those associated with the sloshing of ship tanks with Liquid Natural Gas or with the oscillations of pipelines deployed on the sea bottom or risers. These problems are addressed in a multidisciplinary framework that includes (i) emerging numerical methods, such as the Lagrangian Particle methods, for the prediction of the hydrodynamics loads in sloshing flows and impact problems, (ii) full-scale and laboratory load and response models and correlation methods applied to critical phenomena on ships and offshore structures for the prediction of the safe operational margins and the remaining fatigue life and (iii) damage detection methods correlating the structural response to the presence of defects or damages in materials, components or machinery. Techniques integrating measurements and numerical models by data fusion approaches are specifically developed to provide an extended representation of physical phenomena (like slamming or other FSI problems) with the aim to further the understanding on the underlying mechanisms of fluid-structure interaction. Research applied to the integrated control of the traffic is focused on the design and development of technologies for vessel detection and recognition within a given area and for marine environment monitoring including the tracking of floating objects. In particular, research efforts are addressed to: (i) the implementation of a satellite imagery based automatic system with the ability to detect relevant anomalies such as unauthorized fishing or irregular migration and related smuggling activities, (ii) the development of an Environmental Decision Support System (EDSS) based on several heterogeneous data (e.g. multispectral aerial data, SAR satellite processed data, environmental data, dynamic data, AIS data) for monitoring and quantitatively representing risk factors and notifying events deserving consideration and (iii) the development of Lagrangian numerical methods for tracking floating objects under the effect of wind and currents. The trajectory prediction of persons at sea is an important topic also for what concern the emengency management along with all the issues related to the detection, isolation and reconfiguration of the Shipboard Power System (SPS). In particular, the reconfiguration of the Shipboard Power System (SPS) is a challenging problem embracing a multitude of possible scenarios, goals and decision-making procedures that is pursued by integrating a holonic multi-agent system for the self-adaptive composition and orchestration of services in a distributed environment (MUSA, Middleware for User-driven Self-Adaptation) with a virtual simulator of the electric system validating the reconfiguration plan (MATLAB).

“Design, construction and performance improvement of marine vehicles” is a wide multidisciplinary research area which includes computational and experimental hydrodynamics, hydroacustics and hydroelasticity, metrology, material science, mathematics, electronics and engineering. In particular, the design and the performance improvement are central themes of fluid-dynamics and applied mathematical research including the development and application of: (i) innovative simulation-based ship design multi-disciplinary optimization procedures with uncertainty quantification and reliability-based robust optimization for the design of ship/hull/appendages subject to uncertainty, (i) novel design-space dimensionality reduction methods for shape optimization in ship hydrodynamics and multi-physics problems, (iii) dynamic/adaptive metamodeling and machine learning techniques for the affordable prediction/optimization of ship/hull/component performance and (iv) advanced experimental and numerical tools to support the design, the diagnostics and the performance improvement of marine vehicles for different operative scenarios. A non-exhaustive list comprises advanced methodologies for the study of fluid-structure interaction, advanced experimental and numerical tools for the analysis of the noise and vibration generation and their propagation inside and outside the vessel, experimental methods for the study of wall-flows (Temperature Sensitive Paintings), numerical and experimental methods for the fluid-dynamic analysis of complex flows such as those associated with cavitation phenomena and bubble dynamics, free surface, wave breaking, installation effects and unsteady flow problems (i.e. experimental techniques for detailed flow measurements, such as LDV, PIV, Tomographic PIV; potential and viscous solvers for CFD analysis, such BEM, RANS, DES, LES). Research in smart and innovative materials, such as super-hydrophobic paintings and composite materials, and in new manufacturing processes, such as those involving 3D printers, is undertaken though experimental tests about different water repellent surfaces and systematic test series along with finite element models. respectively.

In the context of “Automation and connectivity”, beside the aforementioned research and development activities related to the Shipboard Power System (SPS) and to the Environmental Decision Support System (EDSS), the theme of marine robotics represents a topical issue for ocean monitoring, exploitation and swarming. In particular, research efforts are focused on four topics: (i) the design and development of prototype AUVs, ROVs, USVs, and USSVs with particular attention to portable modular vehicles that can be easily reconfigured at field in different shapes (e.g. the POP-ART concept foreseeing a ROV, that can be reconfigured as AUV and/or USSV), (ii) the design and development of prototype multi-rotor UAVs for short range cooperation with USVs, (iii) the design and implementation of cooperative guidance and mission control algorithms including cooperative landing of a UAV over a USV and (iv) the design and implementation of cooperative methodologies for seabed mapping and characterization, e.g. automatic detection of seagrass.

3. IMPACT

The research studies and the technological developments within the present AP have an impact at scientific, industrial, social and political levels. Scientific results are disseminated worldwide via publications and conference presentations and their impact has a transnational relevance. On the other hand, industrial, social and political aspects of the research are more inherently related to the granting institution (Italian government, EU commission) and, in the case of marine and maritime technologies, to the specific geo-political context, that is, the Mediterranean Sea.

The AP "Marine Technologies" aims at exploring new research directions, developing innovative solutions and supporting intelligently the stakeholders for the design of products and services along two main directions: (*i*) the Blue Growth, as a relevant paradigm of the Green Economy, and (*ii*) the Smart, Safe and Secure operations at sea, implying also Clean as a bridging feature with the Blue Growth. The concept of Blue Growth adopted by the EU can be explained as a knowledge driven quantum jump in the exploitation of marine resources, qualitatively different from the current exploitation pattern and fundamentally aimed at improving the societal wellbeing. Blue Growth implies a drastic change in the attitude of operators in marine and maritime sectors towards a synergistic, non-conflicting and sustainable use of the sea, still allowing a significant growth. This is recognized as a global challenge but felt particularly relevant for the Mediterranean region, due to ~~given~~ its long history of marine resources exploitation and increasing anthropic ~~human~~ pressure. Clean, Smart, Safe and Secure operations at sea is a topic dictated not only by common sense but also by precise indications provided by the EU Commission. The reduction of accidents has been a priority in last years along with the lowering of their consequences in terms of casualties, loss of properties and pollution. The recent issues related to counteract terrorism, be prepared to local conflicts or manage new immigration routes through the Mediterranean Sea have brought to the fore the need of strengthening security for surface vehicles or installations as well. The abatement of harmful emissions is a benefit investing the entire society, both in terms of human health and opposing climate changes. Facing the above-mentioned topics may turn into an economic advantage for our societies, and for Italy in particular. Moreover, increasing the smartness degree of transportation or ~~in~~ the resource exploitation at sea can provide less-costly solutions for conventional activities, adds new capabilities to the same operations and follows the worldwide trend for a connected and automated world.

To be successful, the AP is involved in creating enabling and cross-cutting technologies; as a byproduct of this activity, the AP knowledge platform lays the foundation for supporting CNR as qualified contact-point for the decision-making process at political level on ocean technology related topics. From a technical point of view, the AP "Marine Technologies" is involved to sustain the development of new regulatory frameworks and standards at EU and International level (IMO). For instance, the AP "Marine Technologies" develops research to define the Energy Efficiency Design Index, a technical measure for GHG emission reduction, or to elaborate standards for the measurement of noise and pollutant emissions, upon which MARPOL rules are based. Its continuous involvement on problem solving and technology development provides also an added-value for high-level education, collaborating actively with national and foreign Universities in training young researchers and engineers in the marine technology sector. The researchers contributing to the AP are involved as lecturers and invited speakers in university courses and conferences, and relatively to the marine technology sector have participated also as chairmen of committees within supporting initiatives at EU level or scientific institutions like, e.g., ITTC (International Towing Tank Conference) and ISSC (International Ship and Offshore Congress). Because of its human capital and laboratories, the AP "Marine Technologies" has been able to participate to important research initiatives and projects, like EU and Italian funded projects, Joint Industrial Projects and many others.

The AP has been contributing to these topics strengthening collaborative research between Institutes and researchers inside and outside DIITET; indeed, innovative and feasible technological solutions for the sea activities increasingly require multi-disciplinary skills and attitude to technology transfer, in order to reach a practical and lasting impact at industrial, social and political level. The AP activity is also based on an important network of research infrastructures, which shapes deeply its own way of pursuing its research objectives: (*i*) extensive use of experiments in its facilities and laboratories to validate first-principle simulations; (*ii*) capability of testing full-scale technological solutions including also open sea trials; (*iii*) support for industrial testing to improve the reliability and efficiency of vehicles, off-shore structures and renewable energy devices; (*iv*) involvement in metrology and in the definition of new measurement standards and techniques. The presence of these key research infrastructures is also one of the drivers which allows the AP “Marine Technologies“ to cluster the efforts of academic and research institutions to participate to national and EU calls in the maritime sector or even to take part at higher level to the decisional processes or EU supporting actions for the definition of future research priorities.

The capability to develop numerical models is the premise to support system design in a more efficient, reliable and accurate way, as a specific mission of this AP to bring into consideration the interaction between systems and the sea environment. The continuous increase of this potential also along unexplored patterns has greater chances to meet the industrial needs for facing new problems related to innovative devices: as occurred in the past for the development of fast transportation solutions, nowadays marine robots, new support vessels for larger or novel off-shore installations, more efficient and silent propulsion are just few examples of industry-driven targets.

In a Green Economy perspective, new industrial possibilities may rise or be encouraged by the AP research activities, increasing also job opportunities or even re-inventing some professional roles. In this framework, some relevant cases for the AP “Marine Technologies” are: development of innovative energy technologies for transportation (low-carbon or zero carbon fuels, after-treatment and energy recovery systems, hybrid propulsion, All Electrical Ship, adaptive Shipboard Power Systems, energy storage, high-efficiency ships with combined production of electrical and thermal energy), mechanical and structural design of renewable energy systems (offshore floating wind-turbines, tidal and wave energy converters, multi-purpose platforms), new materials and developments in material technologies (hydrophobic coatings, self-cleaning and anti-fouling materials with less use of aggressive paintings), systems for environmental monitoring and pollution recovery (monitoring platforms for acoustic and chemical emissions, unmanned surface (USV) and underwater vehicles (AUV).

Many of the above activities have also an indirect impact on building the Big-Data world and, in this perspective, there is an ocean of data worth to feed machine learning processes. The Marine Information System is an example of this: its integration with Observational Networks and on-shore data centers allows for coping with environmental protection, detection of illegal and unauthorized activities, warnings on extreme events. The ship itself, which benefits from weather forecast, can be a node of an Observational Network devoted to sense metocean conditions by the concept of ship-buoy. The ICT competence provides the enabling technologies for the Big-Data infrastructure in the maritime sector. At a smaller scale, the ship itself or the offshore installations are more and more shaping as Big-Data islands. Increasing the passenger experience or his safety during a voyage is nowadays possible tracking his position, conditions and attitude on-board. Extensive on-board diagnostics through sensor arrays already have an impact in reducing unnecessary inspections or providing the early-detection of system failures, up to the management of emergency procedures; the analysis of collected data is also beginning to give further chances to update mathematical models and probabilistic design approaches.

4. EMERGING RESEARCH CHALLENGES

- Self-repairing materials
- Modular and reconfigurable ships and logistics
- Hybrid models, virtual sensing and data fusion
- Bio inspired design
- Big data
- Zero emission activity vehicles
- Fully recycled components (bio-composites)
- Additive manufacturing for metallic materials
- Artificial Intelligence for the applications in smart oceans (unmanned and autonomous ships, marine robotics, swarms…)
- Underwater smart and clean technologies for Ocean and deep sea exploitation
- Micro-drones for ocean swarming
- Floating cities

5. CONCLUSIONS

The AP "Marine Technologies" is deeply involved in promoting excellence in research, in the development of innovative technological solutions, and in supporting also at social and political level a sustainable exploitation of the Oceans.

Excellence in research is witnessed by the involvement of his researchers in terms of publications, patents and important roles in scientific Institutions at national, EU and global level. This has allowed the AP "Marine Technologies" to be successful in attracting grants which have contributed to strengthen its network made of skilled researcher, trained technicians and worldwide infrastructures.

The technology transfer and the multidisciplinary competence play a fundamental role in this AP. Predictive models and technological solutions developed in other fields need to be tailored for the specific needs of the maritime applications or combined into new frameworks built over different disciplines: fluid-dynamics, chemistry, materials and structures, electrical engineering and electronics, system theory, information theory and so on. The trend, as the emerging challenges demonstrate, is for an increasing integration between the different approaches to reach technological solutions which are Smart, Safe and Clean, where smartness assumes increasingly the meaning of automation and connectivity. This implies a considerable effort in "coupling" the different disciplines, which turns not only into understanding interactions and feedbacks, but also into having researcher skills in this AP focused in connecting ideas and theories. As a last point, the role of the research facilities for achieving relevant research targets and for supporting the technological development of marine technology and ocean engineering remains critical and asks to be further strengthened.

Annex: AP_CNR RESOURCES

1. **Description of relevant facilities**

Facility name	Brief description (overall features, purpose,…)	Main characteristics (geometric, operative, …)	Location
Cavitation tunnel	Close-jet type water tunnel for hydrodynamic, hydroacoustic and cavitation tests	• Test section: 0.6m x 0.6m x 2.6m • Maximum water speed: 12 m/s • Pressure range: from 10 to 150 Kpa	c/o CNR INM, Rome
Large Circulating Water Channel	Large scale, depressurisable, free-surface, circulating water channel for hydrodynamic, hydroacoustic and cavitation tests	• Test section: 10m x 3.6m x 2.25m • Maximum water speed: 5 m/s • Press. range: from Atm to 30mbar	c/o CNR INM, Rome
Fluidized bed reactors	Combustion/gasification/DeSOx/heat exchanger units based on fluidized bed reactor technology	Different size test rigs from 40 mm up to 370 mm for hydrodynamic and reacting flow tests	c/o CNR IRC, Napoli
Labs for Catalytic and Advanced Materials	Synthesis and detailed characterization of hetereogeneous catalysts and advanced nanostructured materials	SEM-EDX, AFM, XRD, ICP-MS, FT-IR, DRIFT, RAMAN, TGA-MS, BET, Physi-Chemisorption, PSD, TPR-TPD-MS, thermography, Flame spray pyrolysis, Laser diagnostic	c/o CNR IRC, Napoli
Catalytic test reaction lab	Testing of catalytic process (DeNOx, catalytic	Lab scale structure reactors, fully equipped on-line and off	c/o CNR IRC, Napoli

	combustion, H_2 production, VOC oxidation, CO_2-hydrogenation, H2S removal) under relevant operating conditions for industrial applications with novel catalysts and structured systems	line gas phase analytical systems for gaseous species and (nano)particles characterization	
Diagnostic lab	Detection and Monitoring of primary and trace pollutants (gas phase and nano-particulates) from combustion process	Electrostatic Low Pressure Impactor, Scanning Mobility Particle Sizer, Condensation Particle Counter, GC-MS, TOF-MS, FTIR, UV-Vis, LII, LIF, gas phase analyzers	c/o CNR IRC, Napoli
Polymeric Electrolyte Fuel Cell Test Station.	Activity and Stability Test	Electric Power: 0-10 kW	c/o CNR ITAE, MESSINA
Solid Oxide Fuel Cell Test Station.	Activity and Stability Test	Electric Power: 0-5 kW	c/o CNR ITAE, MESSINA
N° 2 Battery Test Stations.	Battery cyclers	• Electric Power: 0-20 kW @12 V nominal • Electric Power: 0-20 kW @150 V nominal	c/o CNR ITAE, MESSINA
N° 2 Climatic chambers EUCAR 6	• -40° ÷ +180° (HR 5-95%) • -40° ÷ +180°	• 600 l • 340 l	c/o CNR ITAE, MESSINA
Hydrogen Generator Test Station	Activity and Stability Test	Hydrogen Capacity: 0-30 Nm3/h	c/o CNR ITAE, MESSINA
Regenerative Electrolyser Test Station	Activity and Stability Test	Electric Power: 0-10 kW	c/o CNR ITAE, MESSINA
Third Generation Photovoltaic Test Station	Activity and Stability Test	Electric Power: 0-10 kW	c/o CNR ITAE, MESSINA
Adsorption Air Conditioner Test Station.	Activity and Stability Test	Electric Power: 0-10 kW	c/o CNR ITAE, MESSINA
Test bench for electric Propulsion	Eddy current brake	Maxim mechanical power up to 250 kW	c/o Istituto Motori, Napoli
Test bench for electric Propulsion	Asynchronous dynamic brake	Maxim mechanical power up to 100 kW	c/o Istituto Motori, Napoli
Battery test bench	Bidirectional AC/DC power converter	Maximum current 100 A	c/o Istituto Motori, Napoli

Laboratory isolated micro-grid	DC grid connected with energy storage and renewable energy systems	DC voltage 800 V, power load up to 200 kW	c/o Istituto Motori, Napoli
Test Cell fully instrumented	Cells for internal combustion engines testing with gaseous fuels (CH_4/H_2)	200 kW Multi-cylinder engine; 4.2 dm3/150 kW research single cylinder engine	c/o Istituto Motori, Napoli
Non-conventional diagnostics laboratory for optical and research engine	test cell for internal and external combustion engine lab for evaluation ORC and storage system	Research engine until to 3 liter	c/o Istituto Motori, Napoli
e-URoPe	Open-frame ROV/AUV for scientific applications	100cm x 70cm x 90cm 150 Kg weight 200m depth combined acoustic comms-USBL positioning system DVI Fiber Optic Gyro Fiber optic tether with two channels devoted to HR payload	c/o CNR INM, Genova
R2 (Artù)	Open-frame ROV for scientific applications	130cm x 90cm x 100cm 450 Kg weight 500m depth combined acoustic comms-USBL positioning system DVI Fiber Optic Gyro Fiber optic tether	c/o CNR INM, Genova
Proteus (P2-ROV)	Reconfigurable open frame torpedo-like ROV/USSV	140cm x 35cm (diameter) 60 Kg weight 200m depth (ROV mode)	c/o CNR INM, Genova
Charlie	Catamaran USV	240cm x 170 cm 250 Kg weight	c/o CNR INM, Genova

2. Personnel

Profile	Institute	Research topic of interest in the AP (possibly use one or more of the blue keywords listed from pag.3 to 6 in the power point file plus details)	PM per year (rough estimation)
2 Researchers	ISTI	• Emergency management (oil-pollution marine information system) • ICT (Decision support systems) • ICT (On-board data management) • Autonomous Underwater Vehicles • ICT (Remote sensing analysis)	11
2 Senior Researchers	ISTI	• Remote sensing and image diagnostics	3

		• ICT (Decision support systems)	
9 Researchers	IRC	• Advanced diagnostics for combustion formed pollutants • Flame synthesis of nanostructured materials • Water remediation • Fluidized bed reactors • Waste heat recovery • Waste Incineration • Heterogeneous Catalysis (reducing NOx, SOx, CO2 VOC, soot) • Advanced nanomaterials • Water remediation	9
2 Research fellows	IRC	• Fluidized bed reactors • Waste heat recovery • Waste Incineration • Heterogeneous Catalysis (reducing NO_x, SO_x, CO_2 VOC, soot) • Advanced nanomaterials • Water remediation	5
4 researchers	ICAR	• Green transportation: smart on board energy management • Safe, secure and smart operations: emergency management, electrical failures • Advanced ship design, construction and performance improvement: on board systems	24
2 PhD/Research fellows	ICAR	• Green transportation: smart on board energy management • Safe, secure and smart operations: emergency management, electrical failures • Advanced ship design, construction and performance improvement: on board systems	12
33 researchers	ITAE	• Green transportation: energy recovery solutions, smart on board energy management, alternative fuels, electrification/storage, hybrid propulsors, waste management	84
2 Senior researchers	ITAE	• Green transportation: energy recovery solutions, smart on board energy management, alternative fuels, electrification/storage, hybrid propulsors, waste management	4.5
7 Research Directors	ITAE	• Green transportation: energy recovery solutions, smart on board energy management, alternative fuels, electrification/storage, hybrid propulsors, waste management	17

1 Researcher Director	INM	• Green transportation: energy efficiency, low impact on marine • Advanced ship design, construction and performance improvement: simulation based optimization, uncertainty quantification, frontier techniques/tools, new and non-conventional devices, EFD tools, CFD-FEM-FSI tools	6
19 researchers	INM	• Green transportation: energy efficiency, low impact on marine • Save, secure and smart operations: critical load evaluation, after accident procedures • Advanced ship design, construction and performance improvement: simulation based optimization, uncertainty quantification, frontier techniques/tools, new and non-conventional devices, EFD tools, CFD-FEM-FSI tools	164
5 Senior researchers	INM	• Green transportation: energy efficiency • Advanced ship design, construction and performance improvement: CFD-FEM-FSI tools	33
2 Research engineers	INM	• Advanced ship design, construction and performance improvement: CFD-FEM-FSI tools	24
2 Senior research engineers	INM	• Green transportation: energy efficiency low impact on marine • Advanced ship design, construction and performance improvement: new and non-conventional devices, EFD tools, CFD-FEM-FSI tools	10
3 researchers	INM	• Automation and connectivity	24
2 Senior researchers	INM	• Automation and connectivity	18
12 researchers	IM	• Electric Motors • Propulsion Hybrid Architectures • Power Electronic Converters • Storage Systems • Alternative fuels • Dual fuel system optimization • Calibration and optimization of engine performance and exhaust emission; • Optical diagnostics of air-fuel mixing and combustion process in internal combustion engine. • Energy efficiency: • Smart on-board energy management • Engines optimization • Acoustic tests	38

		• Fuel Cell • After treatment technologies • Engine Control • Engine Technology	
3 Senior researchers	IM	• Energy efficiency: • Smart on-board energy management • Alternative Fuels • Engine Technology • Engine Control	9
3 Research Directors	IM	• Energy efficiency: • Smart on-board energy management • Alternative Fuels • Engine Technology	8
1 Research Engineers	IM	• Renewable Energy Sources • Propulsion Hybrid Architectures • Power Electronic Converters • Storage Systems	5

3. Active projects

Project name	Institute	Funding institution	Budget	Funding	Start year, duration
HOLISHIP	INM	EU H2020	11 M€	210 k€	2016, 4 years
NICOP-SHS	INM	US Office of Naval Research	300 k€	150 k€	2017, 3 years
NICOP-PRICO	INM	US Office of Naval Research	450 k$	225 k$	2017, 3 years
IOWA FSI	INM	University of Iowa	-	50 k$	
VinMac	INM	Regione Lombardia	200 k€	80 k€	2016, 3 years
PERMARE	INM	MIUR	3.8 M€	670 k€	2012, 6 years
Navi ad alta efficienza	INM	FINCANTIERI	110 k€	110 k€	2017, 1 year
TRIM	INM, IRC	MIUR	11 M€	1137 k€	2014, 6 years
UNAC-LOW	INM	EURAMET EMPIR	45 k€	45 k€	2016, 3 years
FLOWIS	INM	EDA (European Defense Agency)	1220 k€	228 k€	2016, 3 years
RITMARE IV	INM	MIUR	-	98 k€	2016, 2 years
Deceiving Prop	INM	SEGREDIFESA-PNRM	2000 k€	600 k€	2017, 3 years
ERANET MARTERA ProNoVi	INM	EU H2020	2500 k€	150 k€	2018, 3 years
E-CABIN	INM	MISE-FINCANTIERI through ISTEC	1082 k€	70k€	2017, 2 years
HPEM2GAS	ITAE	EU H2020	2654 k€	415 k€	2016, 3 years

ZEOSOL	ITAE	EU H2020	2167 k€	334 k€	2017, 30 months
FotoH2	ITAE	EU H2020	2579 k€	656 k€	2018, 3 years
NEPTUNE	ITAE	EU H2020	1926 k€	399 k€	2018, 3 years
Tecnologie a basso impatto ambientale per la produzione di energia su mezzi navali	ITAE	PON MISE H2020	18 M€	1044 k€	2018, 3 years
OSIRIS	ISTI	ESA	700 k€	210 k€	2016, 2 years
RITMARE – Attività Straordinarie	IM	MIUR	-	450 k€	2015, 4 years
IMARE	IM	PON	-	500 k€	2017, 3 years
TRIM	IRC	MIUR	10M€	35K€	2015, 4 years
Excellabust	INM	EU H2020	1015 k€	201 k€	2016, 3 years
Ibrhydro	INM	Ministero Trasporti	3947 k€	398 k€	2016, 3 years
EuMarine Robots	INM	EU H2020	4999 k€	52 k€	2018, 3years
Arice	INM	EU H2020	5997 k€	30 k€	2018, 4 years
Ice-climalizers	INM	PNRA	104 k€	9 k€	2017,2 years
MAREA	INM	MIUR	2932 k€	86 k€	2015, 2,5 years
Sviluppo software progettazione e analisi eliche	INM	Italian Navy	137 k€	137 k€	2017, 2 years

PROJECT AREA 19: MARINE TECHNOLOGIES

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